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NATIONAL CONSERVATION LANDS

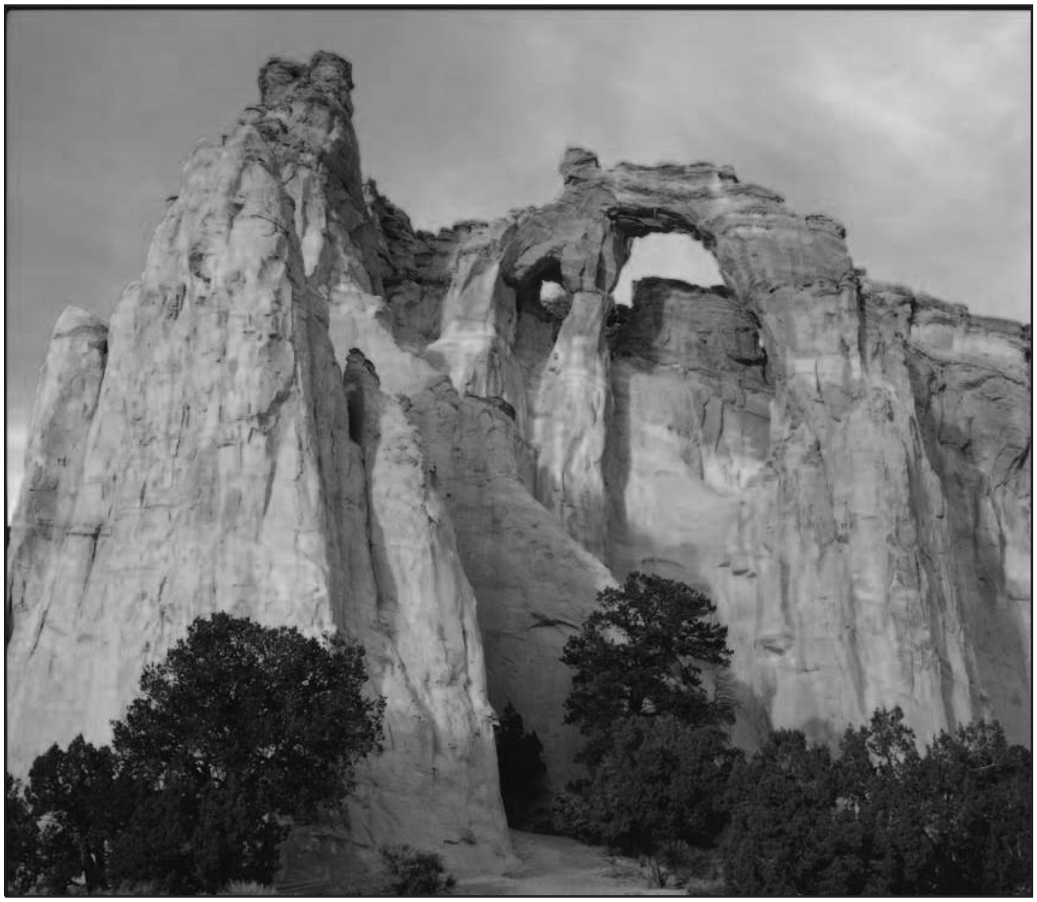
UTAH

GRAND STAIRCASE-ESCALANTE
NATIONAL MONUMENT

20TH ANNIVERSARY

SCIENCE SUMMARY
2006 - 2016

Learning from the Land



United States Department of the Interior
Bureau of Land Management

The mission of the National Landscape Conservation System (NLCS) is to conserve, protect, and restore nationally significant landscapes recognized for their outstanding cultural, ecological, and scientific values.

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Learning from the Land

GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT

SCIENCE SUMMARY

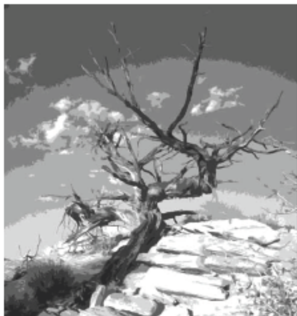
2006 - 2016

SCIENCE SYMPOSIUM

AUGUST 2 4, 2016

KANAB AND ESCALANTE, UTAH

Printed by Grand Staircase Escalante Partners, August 2016



Acknowledgements

The Bureau of Land Management would like to express its appreciation to all who participated in the third *Learning from the Land* science symposium. Many thanks to all who took the time to prepare and make presentations or lead field trips, as well as those who attended sessions. The symposium was a success thanks to the involvement and support of many people, organizations, and businesses including Garfield and Kane counties, Grand Staircase Escalante Partners (GSEP), and Glen Canyon Natural History Association (GCNHA).

As the Assistant Monument Manager, Science & Visitor Services Division, Carolyn Z Shelton has been a steadfast champion of scientific research conducted on GSENM. Carolyn provided overall direction, encouragement, and support for the tireless efforts of GCNHA hosted worker, LeAnn (Bambi) Skrzynski, who coordinated the symposium event as part of the 20th Anniversary celebration for Grand Staircase-Escalante National Monument.

The BLM wishes to thank GSEP staff, Sherry Robinson, for administrative support, Emily Schrepf for fieldtrip reservation coordination, and Katja Knoll for helping summarize journal articles. Our sincere appreciation to BLM staffers Liz Kolle and Linda Tramontano for event -day assistance and fieldtrip coordination; and to all the BLM employees, MAC members, and scientists who served as symposium event presenters, facilitators, fieldtrip leaders, or provided assistance and support.

Further, a thank you to Karen Monsen, for donating her time and talents to several journal summaries. Our highest praise goes to Gretchen Siefried for her unpaid dedication to the preparation and presentation of our luncheon at the Heritage House in Kanab, and to Mary Dewitz for the dedication she showed in designing, compiling and formatting the Science Summary.

Cover photo:www.jt-fineart.com

A special thank you to the following sponsors and supporters:

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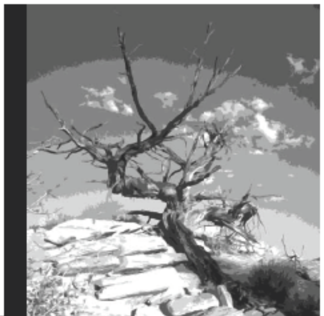

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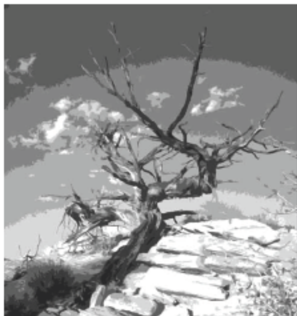


Greeting from the Monument Manager

Grand Staircase-Escalante National Monument and its partners are proud to host this 3rd Science Symposium in conjunction with the 20th Anniversary of the Monument. Much has been accomplished in the 20 years since this Monument was established, and science remains at the forefront. This Symposium provides the opportunity to better understand and to celebrate the research and scientific discoveries over the last 10 years on the Monument.

Grand-Staircase Escalante National Monument is often referred to as the "Science Monument." The roots of that nickname came to us 20 years ago in the words of the Proclamation that the president signed on September 18, 1996.

The very first words of the Proclamation identified the Monument's birth in science and the reason for its designation as a Monument: "The Grand Staircase-Escalante National monument's vast and austere landscape embraces a spectacular array of scientific and historic resources." The proclamation goes on to identify the value of the frontier quality for science: "Even today, this unspoiled natural area remains a frontier, a quality that greatly enhances the monument's value for scientific study." That first paragraph ends with the promise of unparalleled opportunities for science: "The monument presents exemplary opportunities for geologists, paleontologists, archeologists, historians, and biologists."

This Symposium highlights the scientific and historic resources and celebrates the work of those geologists, paleontologists, archeologists, historians, biologists, staff, and many more that have contributed to the body of scientific research, implementation and utilization on the Monument.

Thank you to all the researchers, scientists, universities, staff and citizen scientists that have been so instrumental in sharing the wealth of scientific discoveries and treasures that the Monument holds. Thank you to all our partners, researchers and staff who worked tirelessly to help plan, support and carry out this Science Symposium. And finally, thanks to all of you that have joined us for the Symposium, to learn what scientific treasures the monument holds, to attest to the scientific values for which it was set aside and to support the ongoing science vision for the Monument.

We are all committed to this "vast and austere landscape that embraces a spectacular array of scientific and historic resources." We are all committed to see that "this unspoiled natural area remains a frontier, a quality that greatly enhances the monument's value for scientific study." We are all committed to see that the exemplary opportunities for science on the Monument continue and expand. We are all committed to Grand Staircase Escalante National Monument.

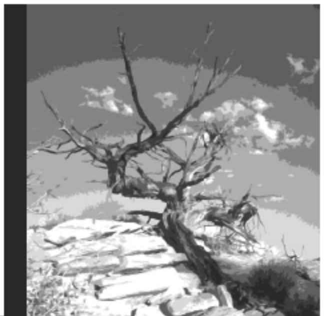
Cynthia Staszak

Cindy Staszak,

Grand Staircase Escalante National Monument
Monument Manage

Greetings from the Monument Manager

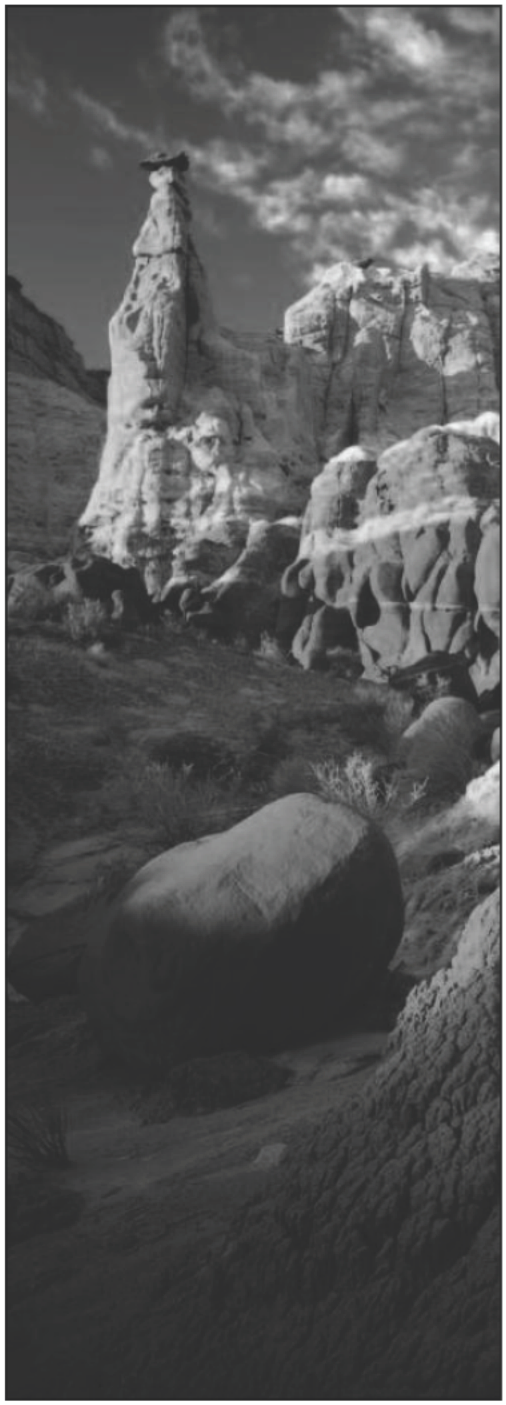
Introduction



This report is a summary of published scientific articles about various topics on Grand Staircase-Escalante National Monument (GSENM) from 2006 to 2016.

The entire articles, plus published papers, theses, dissertations, and many more items of scientific interest, including the proceedings from the 1997 and 2006 GSENM *Learning from the Land* Science Symposia can be found online in the Southern Utah University Special Collections Library at:

suu.edu/page/ special-digital-collections-grandstaircaseescalante-national-monumentcollection



Area known as the Toadstools in Grand Staircase-Escalante National Monument.

FOIA001:01697684

Paleoecology of Grand Staircase-Escalante National Monument: Human Landscape Impacts and Management Implications on the Colorado Plateau

Authors:
Robert M. D'Andrea, R. Scott Anderson, Matthew K. Zweifel, Kenneth L. Cole, and Brittany Burgard

Archaeology and Human History

Reconstructions of climate, fire and vegetation have been created spanning back ~7300 years for Fiftymile Mountain and ~1650 years for Johnson Canyon. These records are based on the analysis of lithology, stratigraphic pollen and charcoal, and plant macrofossils conducted on sediment cores from each site and five packrat middens from Johnson Canyon. They demonstrate landscape change through time due to climate variability and human impacts.

Lake Pasture

- ~7300-3500 cal. yr BP: open juniper woodland with little fire occurrence
- ~3500-140 cal. yr BP: more dense juniper-pinyon (P-J) woodland
- ~140 to -62 cal. yr BP: P-J woodland with decreased fire occurrence and highest rates of erosion in record, likely due to human fire suppression and livestock grazing introduction

Researchers Dr. Scott Anderson, Dave Vaillencourt, Charlie Truettner and Rob D'Andrea recovering the Lake Pasture sediment core.

Researchers Dr. Ken Cole, Dr. Scott Anderson and Brittany Burgard investigating packrat middens in a Wygaret Terrace alcove.

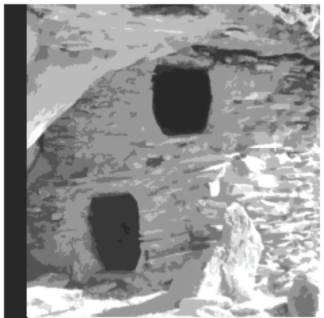
Meadow Canyon

- ~2500-1600 cal. yr BP: large fire event every ~200-300 years
- ~1600 to -63 cal. yr BP: local fire occurrence dramatically decreased, likely due to human fire suppression and management
- ~1650 to -63 cal. yr BP: P-J woodland
- ~1250 cal. yr BP: Virgin Anasazi cultivate corn on Wygaret Terrace
- ~850-820 cal. BP: Virgin Anasazi cultivate corn and bean on the Wygaret Terrace, and bean in Meadow Canyon

These records are important as they (1) document environmental effects of livestock grazing within GSENM cattle allotments, (2) seek a baseline of natural fire and vegetation spanning to the middle Holocene for areas within the Grand Staircase and Kaiparowits Plateau, and (3) assess the significant scientific and historic value of early agricultural archaeological sites in Johnson Canyon and on Fiftymile Mountain.

DOI-2019-06 02370

Deep Human History in Escalante Valley and Southern Utah



Authors:
Joel C. Janetski,
Mark L. Bodily,
Bradley A. Newbold, and
David T. Yoder

Few sites on the Colorado Plateau have had the potential to shed light on human history just after the Paleocene. This site displays layers of occupation beginning over 11,000 years ago (the earliest on the Colorado Plateau) which were fortuitously preserved by sediment occasionally flooding the area and sealing off moisture-resistant artifacts, such as ornamentation in the Paleoarchaic layer.

The paleoenvironment, much cooler and wetter than today, is clearly reflected in the botanical evidence that was preserved, as well as the remnants of Paleoarchaic meals of ducks, beaver and the most surprising find – turkey - which are not found in the younger occupation layers at this site.

As the area experienced drier and hotter conditions, the North Creek Shelter remained occupied, as it was situated to take advantage of nearby highlands and lowlands for game in conjunction with a perennial water source. An anomaly of an unusual mix of ceramic potsherds and corn with the use of atlatls for game about 7000 years ago was noted, then followed by light, occasional use until 1,200 years ago when Anasazi and Fremont habitation coincided.

The Kaiparowits Band of Southern Paiutes lived in the Escalante River headwaters region when the Black Hawk War brought Mormon militiamen to the area.

Fremont-Anasazi Boundary Maintenance and Permeability in the Escalante Drainage

Authors:
Joel C. Janetski,
Lane D. Richens,
and Richard K. Talbot

A chance finding of human remains by a high school student on a field trip at the Ticaboo Town Ruin 35 years ago resulted in a shakeup of interpretation of the Anasazi and Fremont cultural-historical relationships. Formative sites, particularly within the Escalante Drainage of modern-day Grand Staircase-Escalante National Monument and in the period AD 950 to 1100, upon reflection, seem to reflect a blurring of the boundaries between the two cultures. The authors sought to make a determination of the relationships between the two groups by reviewing studies to sort them ethnically and chronologically. From there, tangible remains – ceramics, site plans and architecture – of Fremont, Kayenta Anasazi and Virgin Anasazi could help to distinguish what was taking place in a cultural context.

All signs indicated that the Anasazi moved into a traditional Fremont area during this time - across an ethnic, though permeable, boundary without a cultural continuum. Questions remain about the possibility of intermarriage or trade alliances and the nature of co-habitation within the region.

Archaeology and Human History

The Archaeology and Biology of Early Plant Domestication: Evidence for the Four Corners Potato (*Solanum jamesii)* in Utah

Authors:
Lisbeth A. Louderback and Bruce M. Pavlik

Native plants provide the food and material sustenance of all human societies. The ancient transition from gathering wild, native plants to farming selected genotypes was a crucial turning point in the history of civilization. Maize, beans, and squash had their origins in Mesoamerica and were spread by trade only during relatively recent times. Prehistoric, in-situ domestication, the foundation of modern agriculture, has not yet been documented from western North America.

This project is testing the hypothesis that cultivation/domestication took place on the Colorado Plateau during prehistoric times. We are focusing on biogeographic, genomic and archaeobotanical evidence concerning the Four Corners potato, *Solanum jamesii.*

DeLane Griffin, direct descendent of early pioneer settlers, cultivates *S. jamesii* in his garden and loves to eat the potatoes.

Solanum jamesii in Escalante, Utah. These tubers were produced by one plant in eight months.

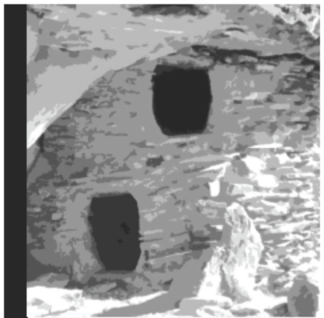
We predict that at certain archaeological sites there are remnant, now apparently wild populations of this species, descended from strains that had once been subjected to domestication. With the demise of the cultural groups that originated and maintained them, these earliest crops ceased to exist and reverted back to what now appears to be wild.

Although once ubiquitous in Escalante (hence the name "Potato Valley"), *S. jamesii* is now hard to find on the landscape. Establishing the cultural significance and potential agronomic importance of *S. jamesii* could enable conservation through better land management practices and local outreach.

Archaeology and Human History

DOI-2019-06 02372

The Paleoarchaic to Early Archaic Transition on the Colorado Plateau: The archaeology of North Creek Shelter



Authors:
Joel C. Janetski, Mark L. Bodily, Bradley A. Newbold, and David T. Yoder

The North Creek Shelter, west of Escalante, is an impressive archaeological site for its comprehensive, tightly stratified record of human lifeways stretching back over 11,400 years ago. From Paleoarchaic to Early Archaic times, the people living under this shelter had access to water, protection from the elements and warmth from its solar aspect in winter, plus in due time, access to good farming land. The excavation also recorded the changes in lifeways resulting from the transition from a wetter, cooler environment as the glacier atop the Aquarius Plateau completely subsided to a drier, warmer region with changes in plants and animals.

Contrary to the transition in plant and animal life and foraging theory, the Paleoarchaic people actually ate a more diverse, but small game menu, processed on site, than Early Archaics, whose upland big game subsistence was augmented by milling seeds - this may reflect the development of gender roles. Adaptive discontinuity is indicated by a puzzling inconsistency of appropriate technology given the animal assemblages of each time period.

Early Holocene Turkey (*Meleagris gallopavo*) Remains from Southern Utah: Implications for the Origins of the Puebloan Domestic Turkeys

Authors:
Bradley A. Newbold, Joel C. Janetski, Mark L. Bodily, and David T. Yoder

Southwestern Puebloan peoples domesticated and used turkeys for several purposes: initially as a source of materials and then also as a food source. Evidence of the materials exists in cordage and in the production of elaborate robes. The mystery is where turkeys came from, as early and middle Holocene sites hold no evidence of them until the Basketmaker Anasazi.

Conventional thought on the origin of the Southwest domestic turkey had them being imported, along with corn, beans & squash from Central America, or from eastern North America. Genetic studies pointed towards a domestic origin.

Fortunately, remains were clearly found in a Paleoarchaic site west of present-day Escalante that were sufficiently complete to point to them as a wild ancestor of Merriam's turkey (*Meleagris gallopavo*), at a time in the Early Holocene when the environment provided habitat for them. These extraordinarily early dates indicate that these flocks may have provided the source of later domesticated Anasazi-era turkeys.

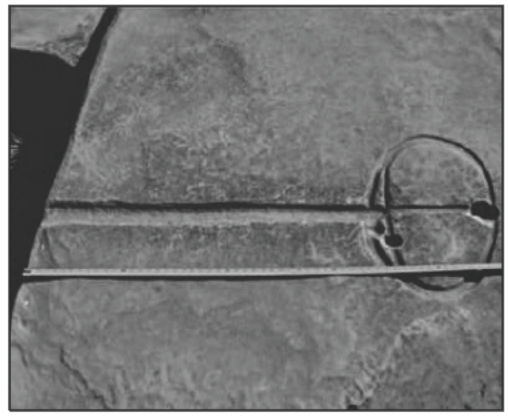
Archaeology and Human History

Water, Pitch, and Prehistoric Indexes: An Analysis of Cup and Channel Petroglyphs

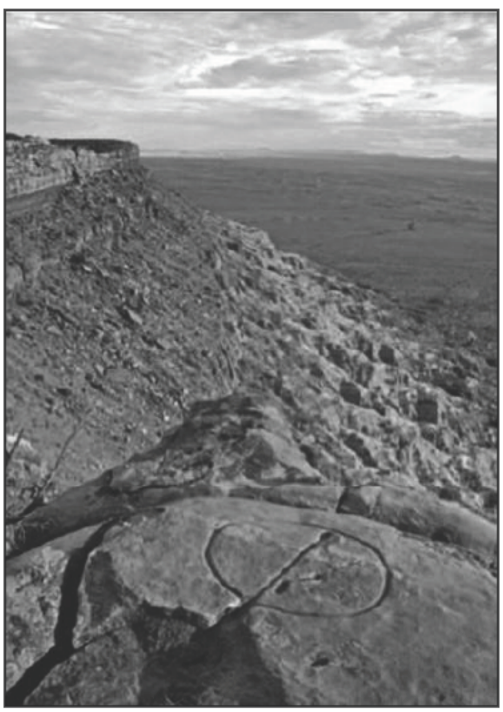
Author:
Michael L. Terlep

Archaeology and Human History

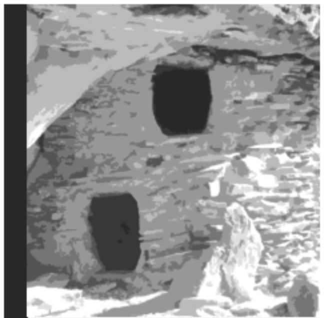
Drawing on Geographical Information System (GIS) techniques, archaeological landscape interpretations and theory, extensive fieldwork, and previous research, this paper provides insight into the cultural affiliation and sociocultural function of cup and channel petroglyphs. The age, origin, and function of these enigmatic bedrock petroglyphs have fascinated archaeologists for decades. The petroglyph size, up to two meters long, and placement at prominent points contributes to the intrigue of cup and channel glyphs. Previous hypotheses for the age and function of the petroglyphs include prehistoric navigational markers to water sources, solstice markers, and historic tar burners. This paper reviews previous work and argues that cup and channel petroglyphs are prehistoric indices of important places, possibly used in water channeling ceremonies. It is further suggested that cup and channel glyphs date to early to mid-formative periods.



Example of cup and channel petroglyphs



Example of cup and channel petroglyphs



The Onset of Small Seed Processing on the Colorado Plateau

Authors:
David T. Yoder, Mark L. Bodily, Sara Hill, Joel C. Janetski, and Bradley A. Newbold

The transition of early peoples, from Paleoarchaic to Archaic cultures, in the desert Southwest is generally attributable to intensively using and processing small seeds into food. There are several ways to verify the occurrence of this process: finding the remnants of microbotanical evidence and seeds in human, fossilized feces or finding the associated tools - the milling stones or baskets used for collecting seeds. This technological change to seed usage could derive from a regional origin and expand with trading networks; evidence to date seemed to indicate that eastern Great Basin archaeological sites exhibited the earliest change.

However, some researchers argued that the reason for a switch to a seed-grinding technology may be attributable to a drier paleoenvironment and hence, is more likely to have begun in drier regions of the desert Southwest. Evidence of milling stones and thus small seed intensification has been found on the more arid Colorado Plateau, within a site that dated back to about 9,000 years ago, although no corroborating copralites or seed evidence were unearthed. The North Creek Shelter artifacts thereby predate the eastern Great Basin and validate the notion that the technology spread from drier regions.

Using packrat middens to assess grazing effects on vegetation change

Authors:
J. Fisher, K.L. Cole and R.S. Anderson

Middens have proven to be amazing resources as packrats collect plants up to 100 meters from their burrows, then repeatedly urinate and defecate over the pile, which effectively seals them into time capsules. To gain a better understanding of the response of an arid landscape subject to livestock grazing, these packrat middens can be used to analyze sites through both time and space. The authors used the plant debris assemblages of pollen and macro fossils found in middens that cover the past 1,000 years to understand long-term vegetation changes in the Glen Canyon area of the Colorado Plateau.

Interestingly, the midden components clearly showed that winter and spring cattle grazing helped control invasive exotic red brome and cheatgrass, although comparisons to the paleoenvironment are unambiguous that grazing negatively affects plant communities. This study validated others and concludes that grazing can alter above- and below-ground architecture, plant cover & composition, plant sex distribution and species richness; it also diminishes native and exotic plant communities.

Archaeology and Human History

Ecosystem Services and Economic Benefits of Beaver Restoration in the Escalante Basin, Utah

Author:
Mark Buckley

The landscape in which we operate today bears little resemblance to that of the time before beavers were effectively eliminated from the watersheds of Grand Staircase-Escalante National Monument and the surrounding region. The Escalante Basin can support 1300 colonies based on its habitat, causing a flattening of the hydrograph to deliver a longer period of peak flows instead of a spike in late spring. Beaver impacts can include ameliorating flooding severity and velocity by increasing storage, water depth and groundwater recharge plus filtering pollutants, reducing temperature and sediment delivery downstream. These changes translate into extended wetland and riparian areas that are beneficial for increased fish and animal habitat plus of economic value to regional people.

Escalante Basin residents spend money for drinking water treatment, to build reservoirs to impound water, to guard their property against flooding, and then must dredge reservoir sediment periodically. Beavers provide these services: in addition to the recreational value of increased hunting, fishing, and wildlife-watching, agricultural and municipal users gain millions of dollars per year in benefits or avoided costs from beaver-inhabited watersheds.

Authors:
Claire Crow and
Charles van Riper III

Avian Community Responses to Juniper Woodland Structure and Thinning Treatments on the Colorado Plateau

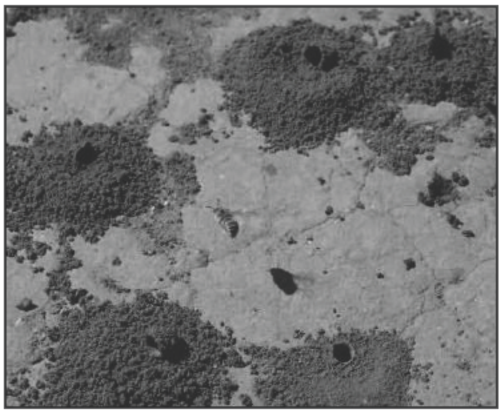
Conservation and restoration prioritization for adaptive management strategies in western land management require analyses of potential ramifications to make informed decisions. These authors studied the composition of bird communities in small, 10-acre plots following mechanical-thinning of pinyon-juniper woodlands in a variety of arid, Colorado Plateau public lands (under the management of the National Park Service, Bureau of Land Management, and U.S. Forest Service) as implementation of fuels-reduction. The Grand Staircase-Escalante National Monument served as the site with the least amount of annual precipitation, with sagebrush as its dominant shrub species.

The authors caution that the existing avian breeding community, pre-treatment, is the result of an altered fire regime and may not be representative of the assemblage from a fully-functioning pinyon-juniper habitat. Best management practices based on this work would entail a management plan for numerous small-scale treatments - whether prescribed fire or mechanical thinning - that emphasize successional stage variety but exclude tree populations characterized by mature trees or that are mainly composed of pinyon pine.

Biology and Wildlife

Bee haven: The significance of Grand Staircase-Escalante National Monument for native bees

Author:
Olivia Messinger Carril



Most of North America's bees nest in the ground, like this *Diadasia* nesting along Hole-In-The-Rock Road.

A comprehensive study of the bees of Grand Staircase-Escalante National Monument was conducted between 2000 and 2003; over that period over 650 species of bees were discovered including nearly four dozen species that are new to scientists. These bees represent 53 genera, and all bee families found in North America.

Our study included intensive surveys in forty-eight plots, sampled with nets bi-weekly for the duration of the flowering season, and revealed a healthy population of native bees including ground-nesters, twig-nesters, cleptoparasites, narrow specialists, broad generalists, solitary, semi-social, and eusocial species. Several of the collected bee species are significant range-extensions; bees previously thought to be restricted to environments further south have found suitable habitat among the diverse landscapes of GSENM.

Similarly, three bee genera new for the state of Utah were discovered. Though many bee species in GSENM are widespread, a handful are rather localized, usually along riparian areas and wet meadows, indicating the importance of protecting flowering resources in these rarer environments. GSENM protects one of the richest bee faunas in the west; the large elevation gradient, incredible number of flowering plants, and the mosaic of habitat and landscape types all contribute to support and maintain this richness.

A digger bee, *Anthophora*, visiting Penstemon species in Grand Staircase-Escalante National Monument.

Biology and Wildlife

Authors:
Melissa S. Siders and Wesley Jolley

Roost Sites of Allen's Lappet-browed Bats (*Idionycteris phyllotis*)

Using three female *I. phyllotis* tagged with radiotransmitters to locate their roost site within Grand Staircase-Escalante National Monument, the authors followed this incredibly rare bat to better understand its roosting requirements. This roost site is at the extreme northern edge of, if not beyond, *I. phyllotis*' described range, yet earlier records in GSENM indicated roosting sites even further north.

While study of foraging behavior was foiled for lack of better tracking methods, radiotelemetry combined with infrared night-vision goggles enabled the site to be characterized. This maternal colony with lactating females was located nearly five km from the capture site and it consisted of at least 15 bats among three roosts within a remote, small canyon, in the top half of a large, highly fractured, northwest-facing cliff. As little is known about *I. phyllotis'* habitat characteristics, other than a wide variety of roosting sites ranging from rock crevices to abandoned mines, this study indicated a preference for rock fissure roosts.

Authors:
Nichole N. Barger, Henry D. Adams, Connie Woodhouse, Jason C. Neff and Gregory P. Asner

Influence of Livestock Grazing and Climate on Pinyon Pine (*Pinus edulis*) Dynamics

Introduction of livestock occurred in tandem with an unusual period of cool, wet weather around the turn of the last century in the Grand Staircase-Escalante National Monument region of the Colorado Plateau. Historical photo comparison of pinyon pine stands with current conditions has been shown to indicate an increase of nearly twofold on historically grazed sites, while overall tree cover remained the same as compared to relatively ungrazed sites with comparable substrate, topography, elevation and climate regime.

While grazing and other anthropogenic causes seemed to have little effect on pinyon establishment, the most important factors for growth were low temperatures in June and winter through early summer precipitation.

These are important considerations for determining appropriate land management of the dominant vegetation type (pinyon-juniper) in the western U.S. The authors contend that the slow regeneration time of pinyon pine combined with the likelihood of a general drying and warming climate in years to come, should be cause for great caution in attempting to thin or remove pinyon-juniper woodlands to achieve a historic condition.

Biology and Wildlife

Discovery of a new bee species excavating nests in sandstone: *Anthophora pueblo* (Hymenoptera: Apidae)

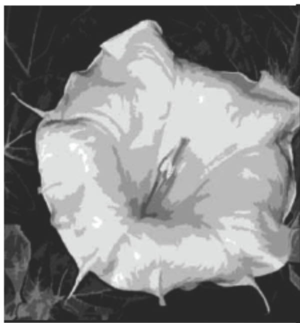
Authors:
Michael C. Orr,
Frank D. Parker,
Terry Griswold,
and James P. Pitts

A female of the new species, *Anthophora* (Anthophoroides) *pueblo*.

The Anthophora (Anthophoroides) are a small group of western North American bees for which the nesting biology is poorly known. Our paper describes the new species *Anthophora* (Anthophoroides) *pueblo* and the discovery of it nesting in sandstone, a behavior rarely seen in bees. We found *Anthophora pueblo* nesting in sandstone at two sites and believe it also constructed similar nests at three other sites, one of which is located in Grand Staircase-Escalante National Monument. There, nests were found patchily throughout a vertical sandstone face. They nested densely and almost exclusively in weaker sandstone, given the energetic burden of excavating harder sandstone, potentially causing the additional problem of competition for nesting space. However, benefits may offset these costs. As all sites were located near washes, ground-nesting bees may be washed away by flash floods, while elevated nests would usually be spared. Nesting above ground may also reduce contamination of nests by harmful, soil-borne pathogens. Further research is necessary to confirm and quantify the costs and benefits of nesting in sandstone.

The GSENM site, located near Kitchen Corral Springs. Thousands of nests were found throughout this sandstone outcropping.

Biology and Wildlife

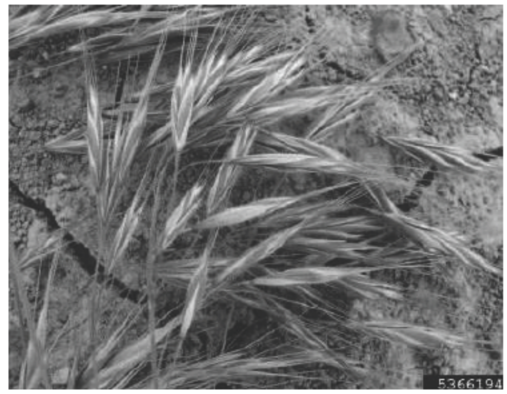


Evaluating dominance as a component of non-native species invasions

Authors:
Alycia W. Crall, Gregory J. Newman, Thomas J. Stohlgren, Catherine S. Jarnevich, Paul Evangelista, and Deb Guenther

In this data re-analysis, the authors investigated the invasive and dominance potential of an exotic annual, cheatgrass (*Bromus tectorum*), in the eighteen vegetation types of Grand Staircase-Escalante National Monument. While many studies seek to determine the likelihood of non-native plant establishment in a given habitat, adding relative cover of a dominant, exotic species in this snapshot of resource condition may help to predict susceptibility and may be a better indicator for decline in native plant richness.

The factors that promote species relative cover compared with establishment of a generalist where the limiting factor for a plant community is availability of water held true for the dominance of cheatgrass, except at smaller scales. Land managers should be aware that managing for colonization prevention and control of cheatgrass post-invasion may best be achieved by early detection and targeted control in vegetation types with the highest quality potential and species diversity.



Bromus tectorum (cheatgrass) Photo courtesy of USFS

Long-term effects of chaining treatments on vegetation structure in pinon-juniper woodlands of the Colorado Plateau

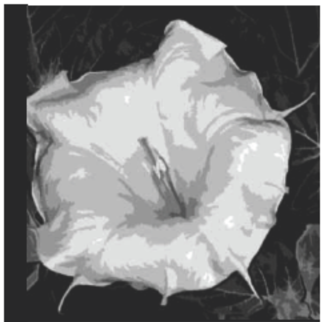
Authors:
Miranda D. Redmond, Neil S. Cobb, Mark E. Miller, and Nichole N. Barger

Changes in management objectives for western U.S. lands have necessitated a better understanding of the long-term impacts from chaining treatments, a method of tree reduction, of pinon-juniper woodlands. The authors describe the importance of analyzing treated pinon-juniper (P-J) ecosystems because P-J dominates much of the public lands and historic changes are important to understand in the context of mitigating wildfires and diversity. Bureau of Land Management's Grand Staircase-Escalante National Monument was chosen for their study as it afforded a history of chaining, with control stands for comparison. Treatments were analyzed and compared for tree density, herbaceous cover and soil erosion.

The on-going method of treatment was shown to have intended and unintended consequences in the study areas. While the P-J removal in this study, after 40 years, showed an increased perennial grass cover, the grass was a nonnative. Long-term diversity was not affected by chaining. Trees were obviously reduced in density when chained, but overall tree regeneration was slow and resulted in only 1/10 the number of pinon pine which may affect wildlife dependent upon them. Treated areas also had less biological soil crust and more bare mineral soil than untreated lands which could affect erosion and watershed sediment loads.

Rangeland Ecology and Botany

The myth of plant species saturation



Clearly exotic plant species are expanding their ranges the world over, causing land management concern and requiring analyses to protect the habitat of native species for any number of reasons. Vegetation sampling in Grand Staircase-Escalante National Monument was used to study whether plant communities could become 'saturated' to the point that exotics could no longer find resources allowing their invasion, or push native plant species out by out-competing and extirpating them.

Oddly, the authors have noted that Pacific Northwest counties with the richest number of species show a consistent trend of exotic plant invasion, countering the myth of plant saturation. Whether that is because native species are slower to extirpate or whether the mix of native and exotic can coexist is central to determining land management objectives and priorities. The authors call for greater vigilance on early detection and treatment by building local and regional maps plus better models to predict expansion of noxious species.

Authors:
Thomas J. Stohlgren, David T. Barnett, Catherine S. Jarnevich, Curtis Flather, and John Kartesz

Scale and plant invasions: a theory of biotic acceptance

The prevailing theory for exotic plant invasion has been heavily influenced by the example of the vulnerability of tropical islands, which often leads to the extirpation, or near-extinction of endemic species. That simplistic relationship was reinforced by small-scale constructed communities that indicated diverse communities were more resistant to invasion. This paradigm is overdue for an overhaul by studying six varying scales and the relationships between species richness and cover at each spatial increment. From a square meter in scale, all the way to the central U.S. region, including the 14 vegetation types exhibited at Grand Staircase-Escalante National Monument, these authors sought to better quantify the theory of biotic acceptance.

The results indicated that exotic invasives are not a certainty for elbowing aside native vegetation, although greater scrutiny needs to be given in establishing the connection between exotic species cover and exotic species richness. Disturbance, plentiful resources and habitat variability seemed to contribute to the ability for native and exotic plants to coexist and may give hope for the resistance of native plants.

Authors:
Thomas J. Stohlgren, Catherine Jarnevich, Geneva W. Chong, and Paul H. Evangelista

Rangeland Ecology and Botany

Prioritizing Conservation Effort through the Use of Biological Soil Crusts as Ecosystem Function Indicators in an Arid Region

Authors:
Matthew A. Bowker, Mark E. Miller, Jayne Belnap, Thomas D. Sisk and Nancy C. Johnson

Past conservation efforts have been determined mainly by species-based analyses for lack of a good model of ecosystem function. Biological soil crusts (BSCs) exhibit qualities that are easily quantifiable, found in a variety of arid habitats, and afford a close approximation of ecosystem resiliency to disturbance. Using the large, arid and complex landscape of Grand Staircase-Escalante National Monument as the study area, the authors developed a proxy model to help land managers determine conservation priorities. Sustained livestock use has been the predominant disturbance to the surface of the study area, so rangeland-health protocol based on departure from reference conditions was used as an estimation of potential degradation. Biodiversity-based prioritization areas were predicted with similar results to the BSC model. Flexible tools are essential for land management planning and the results of the BSC model appear to fulfill that need, but may also be used in conjunction with biodiversity-based indicators, as validation. With dissertations increasing globally, BSC modelling could help for conservation of valuable ecosystem services that will be of vital importance to those who live in these landscapes.

Revisiting classic water erosion models in drylands: The strong impact of biological soil crusts

Authors:
Matthew A. Bowker, Jayne Belnap, V. Bala Chaudhary, and Nancy C. Johnson

Throughout the arid drylands of the world, the difference between desertification and a functioning ecosystem can be as simple as controlling erosion through soil stability. While most factors of soil stability are related to unmanageable properties of soil, geography, or weather, biological soil crust (BSC) development can be a tool for land management to proactively counteract erosion. Biological soil crusts are commonly found on arid drylands, such as Grand Staircase-Escalante National Monument, which has a high capacity for BSC development and was the chosen setting to model water erosion controls. The results of the study indicated that the physical properties of the cyanobacterial macro assemblage of BSCs were the primary reason for resistance to wind (and likely water) erosion, although chemical bonding also occurs and its effectiveness is variable across the eight widely varying types of soil. Promoting land management practices which serve to extend the development or range of BSCs is, therefore, a cost-effective and practical means of stabilizing arid drylands in prevention of desertification.

Ecosystem Dynamics and Soils

Evaluating Plant Invasions from Both Habitat and Species Perspectives

Authors:
Geneva W. Chong, Yuka Otsuki, Thomas J. Stohlgren, Debra Guenther, Paul Evangelista, Cynthia Villa, and Alycia Waters

Resource managers need to have a significant range of tools to combat the biological invasion of non-native plants. These authors used the great diversity of isolated habitats of Grand Staircase-Escalante National Monument to combine species and habitat approaches to identify areas that could potentially benefit from concentrated invasive species control techniques. Identifying the common traits that determine highly invasive plants has been unsuccessful or may be variable depending on landscape conditions. Likewise, landscape-sized habitats have resisted the characterization of patterns that can be described as particularly vulnerable to invasive species.

Although this study was able to identify that moist sites at lower elevations with higher levels of soil phosphorus were more susceptible to invasion, that determination was disturbing because it occurred in places where management would harm native species and cherished water resources, plus (with the exception of cheatgrass) it coincided with areas that had little soil crust cover that has exceptionally long recovery needs. It is hoped that management frameworks will be adaptable to change over time and land-use patterns.

A simple classification of soil types as habitats of biological soil crusts on the Colorado Plateau, USA

Authors:
Matthew A. Bowker and Jayne Belnap

Ecological indicators are critical tools for proper resource management planning and land management, especially for non-specialists charged with conservation prioritization. The authors have prepared a tool that provides an effective assessment of eight soil functional types for biological soil crust (BSC) habitat determination for much of the Colorado Plateau, based on the study site of Grand Staircase-Escalante National Monument. With the addition of soils derived from granite and basalt, the classification tool would essentially be applicable to the entire Colorado Plateau.

While BSCs are a complex community of microbial elements that are appropriated by lichens and bryophytes, BSC habitats are most significantly associated with various types of soil in arid lands around the globe. The soil type least likely to harbor BSCs were bentonitic clay soils, characterized by properties that are difficult for many plants, and possibly BSCs, to inhabit. The soil types are easily mapped from existing geological soil surveys, allowing the formation of the BSC predictive range model based on their affiliations, although the authors caution against protecting reserves at the expense of a fully functioning BSC community beyond the three most affiliated soil types.

DOI-2019-06 02383

Untangling the biological contributions to soil stability in semiarid shrublands

Authors:
V. Bala Chaudhary, Matthew A. Bowker, Thomas E. O'Dell, James B. Grace, Andrea E. Redman, Matthias C. Rillig, and Nancy C. Johnson

Prevention of desertification and soil degradation is a primary goal in the management of semiarid or arid landscapes of the southwestern United States, including Grand Staircase-Escalante National Monument. In fragile sage shrublands, little is known about soil organisms and assemblages such as the collaborative community of biologic soil crust (BSC), plants and arbuscular mycorrhizal (AM) fungus. There was no evidence in this study that soil organic matter contributed to soil stability.

While each of the three components of the community (BSC, plants and AM fungi) provided strengths in a different aspect of soil stability, the partnership was critical to creating soil stability. While this biological community serves the semiarid shrublands well, it does not translate to habitats with a moderate amount of moisture, such as would be found on the banks of a riparian area. A system approach is most likely to be beneficial in the land management practices that can promote land cover and retard the erosional processes that lead to dissertations.

Researcher Chaudhary samples soil on her first foray into GSENM.

Modelling invasion for a habitat generalist and a specialist plant species

Authors:
Paul H. Evangelista, Sunil Kumar, Thomas J. Stohlgren, Catherine S. Jarnevich, Alycia W. Crall, John B. Norman III, and David T. Barnett

Land and resource managers would benefit greatly from a reliable model to predict distribution of invasive non-native species. While survival strategies can be lumped into simple categories of generalists or specialists, a species potential for invasiveness can be analyzed from its own traits or from the opportunities provided by its potential habitat on a given landscape. The authors used Grand Staircase-Escalante National Monument as the study site for comparing five commonly used invasive plant models for predicting habitat of one generalist invasive, cheatgrass (*Bromus tectorum*) and a specialist, tamarisk (*Tamarix chinensis*).

Cheatgrass is so successful in its dispersal that it has managed to become the second most common species in the monument, resulting in a consistent lack of all models' ability to predict habitat types that would be resistant to its colonization. Alternately, the specialist tamarisk was strongly linked to its overland proximity to water in three models. Overall, without a clear model that could predict suitable habitat for both types of invasive species, a range of models will likely best predict a species' invasiveness potential.

Ecosystem Dynamics and Soils

Application of BLM's Assessment, Inventory and Monitoring Strategy at GSENM: Community Phases and Annual Biomass as Derived from 2014 Field Data

Authors:
Robert M. D'Andrea, Kevin H. Miller, and Momoka Maeda

Grand Staircase-Escalante National Monument (GSENM) has implemented BLM's Assessment, Inventory and Monitoring (AIM) strategy since 2013. This strategy provides scientifically sound and technically defensible multi-scale monitoring of multiple resource conditions to support management and decision-making. Applications include determining plant community composition to allow spatially-explicit estimates of forage availability using ecological site descriptions (ESDs). Results compare forage production estimates from ESDs based on determination of state and community phase from AIM data with those determined from rangeland health monitoring.

The 2014 AIM data demonstrate that 71.4% of plots analyzed for which ESDs allow determination of state and community phase (28 of 50) were in non-reference condition. The average actual state grass-forb annual biomass was significantly lower than that indicated by ESDs, demonstrating that less forage is available for livestock than reference conditions would suggest.

Vegetation community compositions document the presence of invasive species in all non-reference condition communities as well as the invasion of pinyon pine and juniper into grass and shrub communities. These results could help influence GSENM management objectives and demonstrate the utility of the AIM strategy in GSENM.

Researchers Rob D'Andrea and Momoka Maeda conduct soil classification and vegetation survey within a desert blackbrush community plot.

Researcher Rob D'Andrea analyzes a stratigraphic soil profile within a desert blackbrush community plot.

Ecosystem Dynamics and Soils

Early and late successional biological soil crusts, cattle, and climate change: A landscape-scale survey in southern Utah

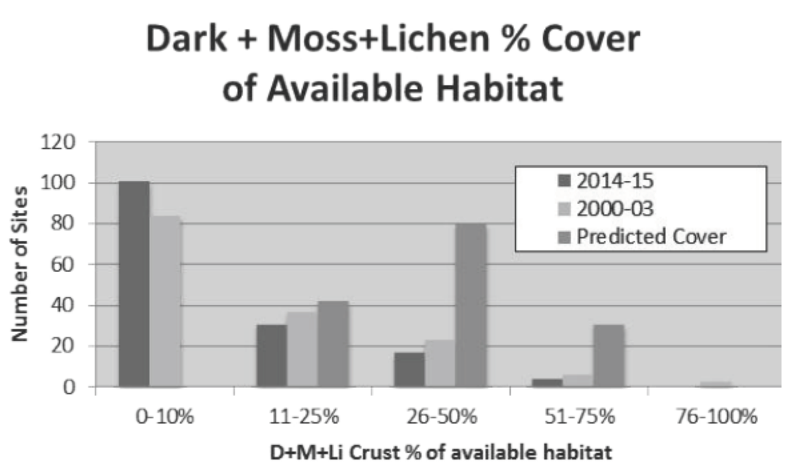
Authors:
David deRoulhac, Collin Smith, and Mary O'Brien. Manuscript in process

In 2014-15, Grand Canyon Trust staff and volunteers completed a survey of biological soil crust (biocrust) conditions throughout GSENM. The survey chose 176 sites based on accessibility and these sites' high (>20%) crust cover potential with high susceptibility to erosion to identify the most biocrust-dependent ecosystems in the Monument. The survey distinguished lightly pigmented (early successional) cyanobacteria-dominated crusts, darkly pigmented (mid-successional) cyanobacteria-dominated crusts, and moss and lichen (later successional) crusts at 153 sites, plus 23 sites where the study conflated dark and light cyanobacteria-dominated crusts.

The 153-site set was compared both to the crust cover measured by the 2000-2003 rangeland health survey and to a model (Bowker, et al. 2006), which predicts potential mid- and late-successional crust cover on the Monument. Analysis found no significant difference in distribution of mid- to late-successional crust cover values from 2000-2003 to 2014-2015. Both surveys recorded mid- and late-successional crust cover that was significantly below crust cover potential

predicted by the model. Transects in pastures ungrazed by cattle for 15 years showed, on average, higher light cyanobacteria-dominated crust coverage than transects in grazed pastures.

At an overwhelming number of sites, biocrust development is being arrested at a light cyanobacteria-dominated (i.e., early) successional stage if biocrusts are present at all. Livestock trampling is cumulative with predicted arrest of mid- and late-succesional stage biocrusts due to higher temperatures (Ferrenberg, et al. 2015).



Ecosystem Dynamics and Soils

Microbial Communities of the Jurassic Navajo Sandstone and Their Role in Shaping the Landscape

Authors:
Harry D. Kurtz, Jr. and Sukhpreet Kaur

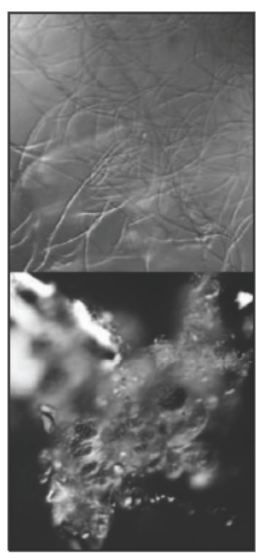
Microbes surround us, even in the dry and seemingly barren world of the Escalante Canyons area. Their presence within the sandstones and sediments help to shape and color the landscape, resulting in the spectacular landscape found in the GSENM. When we examine the sandstone surfaces, we find a robust community of microbes that provide several services reflected in the surrounding landscape.

Through the production of polymers and filamentous cell growth, these microbial communities harden the stone surface, making it more resistant to the effects of wind and water. It also serves to clog pores in the sandstone, reducing the ability of water to infiltrate the otherwise porous sandstones. The clogged pores may act as a vapor barrier to condense internal humidity, providing the community with water to support metabolic activity.

These communities provide for the reduction and movement of iron, too, by removing the oxidized iron surrounding the sand grains making up the sandstone and moving that iron through the ecosystem. This phenomenon is at least partially responsible for the colors we see when looking at the landscape.

On a more fundamental level, the production of polymers that function to capture iron and other metals such as cobalt, combined with modifications of evaporation rates, means these communities are adapted to moderate temperatures to a preferred level when water is present and perhaps serve as a biofilter to capture essential metal ions in a habitat that is not rich in these metals.

Left: Images of small scale features associated with microbial growth. In the top image, V-shaped undercut features are seen and can be found in wind-abraded grooves. In the bottom image, a rock visor is shown. In both cases, it is the resident microbial community hardening the rock surface to allow the feature to develop.



Right: Photomicrographs showing examples of photosynthetic bacteria that are found within the stone surfaces of the Escalante Canyons area.

Ecosystem Dynamics and Soils

Broad-Scale Assessment of Rangeland Health, Grand Staircase-Escalante National Monument, USA

Author:
Mark E. Miller

A new qualitative assessment protocol evaluating soil/site stability, biotic integrity and hydrologic function for rangeland sustainability was applied to over 500 sites across Grand Staircase-Escalante National Monument over a three year period. This technique, rather than traditional methods based simply on key forage species or its similarity to a single idealized climax community, was based on recommendations from expert panels that the most important component of a fully functioning rangeland is soil conservation and it requires assessment methods that can be accurately captured by remotely sensed imagery, then evaluation by an interdisciplinary team of resource specialists.

As grazing is the most substantial land use on Grand Staircase-Escalante National Monument, and, at the time of publication, Interpreting Indicators of Rangeland Health (IIRH), had been widely adopted but not scientifically applied as a case study, the author sought to analyze site-specific management strategies and broadscale patterns at different ecological types of sites. Feedback by practitioners of the IIRH technique included a broadened perspective of what constitutes “rangeland health” and an expansion of discussions among a more diverse stakeholder group. The site assessment results indicated that past management was ecologically ineffectual and the sites with optimal production potential were most likely to be in the worst shape.

Soil carbon storage responses to expanding pinyon-juniper populations in southern Utah

Authors:
J.C. Neff, N.N. Barger, W.T. Baisden, D.P. Fernandez, and G.P. Asner

One of the emerging possibilities for climate change mitigation is looking for alternative, or enhancing, ways to sequester carbon. Although soil already holds more carbon than all plant life and the atmosphere combined, unsustainable agricultural techniques contribute non-stabilized carbon to exacerbate problematic aspects of the carbon cycle. The authors sought to determine how land use changes in management techniques for the expansion of pinyon-juniper (P-J) woodlands in arid ecosystems could affect soil carbon storage.

By quantifying soil organic carbon dynamics using canopy age as a surrogate for the passage of time, these data showed that significant increases of soil carbon and nitrogen storage have resulted below the canopies of proliferating pinyon. In this specific type of rangeland, grazing had no apparent effect on soil carbon. However, these surface organic matter pools’ unstabilized nature indicates the carbon is vulnerable to disruption that increases oxidation or decomposition – techniques such as thinning and overstory removal to prevent wildland fire would exacerbate the problem. There is little indication that longterm carbon storage in P-J stands recruited in the 20th century is a viable carbon sink.

Ecosystem Dynamics and Soils

Atmospheric mineral dust in dryland ecosystems: Applications of environmental magnetism

Deposited dust, deriving from sources far from its current residence, can be traced by its magnetic properties and likely deposition within the last several hundred years within the dry uplands of the Colorado Plateau, including Grand Staircase-Escalante National Monument. These fine-grained wind-blown sediments contain important nutrients and retain moisture for dry-land ecosystems that can be lost when re-mobilized by human uses of resources, except where they are captured by the physical network of biologic soil crusts.

Results indicated that fly ash magnetite is being deposited, most likely resulting from the combustion of coal at the nearby Navajo Generating Station in this case, which can be cause for concern in human health, however aeolian magnetite does not allow for dust source fingerprinting. Using techniques for measuring magnetic susceptibility could help to make management decisions based on this field sampling tool which could be employed to determine superficial soil properties in plant communities to help stem the expansion of exotic invasive species such as cheatgrass (*Bromus tectorum*).

Authors:
Richard L. Reynolds, Harland L. Goldstein, and Mark E. Miller

The promise and the potential consequences of the global transport of mycorrhizal fungal inoculum

While the benefits of using mycorrhizal fungal inoculum may be substantial for future agricultural or horticultural applications, ecological analysis of potential outcomes must be the initial step, to insure successful outcomes with the lowest risk of ecological damage. The authors explore how the global movement of mycorrhizal fungal inoculum can help resolve ecological issues by assisting in bioremediation, habitat restoration and improving the success of agriculture (in particular concerning arbuscular mycorrhizal and ectomycorrhizal fungi) while recognizing that some poorly vetted species could open a Pandora's box of ecological portent.

Three recommendations are made to help guide best management practices for mycorrhizal treatments: determine the necessity of inoculation and its likelihood of success, use a local inoculum source if at all possible, and if not, a sterile culture is advised. While additional research to determine the likelihood and extent of any given species' negative impact in the environment is warranted, the guidelines provided here will provide keys to understanding how best to achieve benefits without concomitant and unintended consequences.

Authors:
Mark W. Schwartz, Jason D. Hoeksema, Catherine A. Gehring, Nancy C. Johnson, John N. Klironomos, Lynnette K. Abbott, and Anne Pringle

Using New Video Mapping Technology in Landscape Ecology

Authors:
Thomas J. Stohlgren, Margot W. Kaye, A. Dennis McCrumb, Yuka Otsuki, Betsy Pfister, and Cynthia A. Villa

Landscape ecology is heavily reliant upon the ability of researchers to accurately characterize the resources in question and to clearly convey the results to land managers, decision makers or the general public. Ecological monitoring through video mapping technology linked to a Geographic Information System (GIS) can take ground-truthing to a whole new level by monitoring large, complex areas cheaply and quickly with less inference than monitoring conventional plots, and more accurately than aerial photography. Multimedia files linked to maps are easily exported to collaborators or resource management.

The authors demonstrated the technique on elk-grazed aspen groves in Rocky Mountain National Park (RMNP) and on the biological soil crusts of Grand Staircase-Escalante National Monument (GSENM). GSENM's noxious, exotic cheatgrass problem was shown to be of far greater magnitude than previously perceived. RMNP's concerns of unsustainable herbivory on aspen groves were shown as locally, but not regionally, severe: aerial photography had missed hidden aspen stands and patches of regeneration. These demonstrations of the power of video mapping technology were combined with enthusiasm for its ability to better incorporate data into visual and spatial applications for communicating ecological conditions.

Ecosystem Dynamics and Soils

Architecture and formation of transgressive-regressive cycles in marginal marine strata of the John Henry Member, Straight Cliffs Formation, Upper Cretaceous of Southern Utah, USA

Authors:
J.A. Allen and C.L. Johnson

Between 83 and 92 million years ago south-central Utah was a coastal region with a tropical climate. Large rivers flowing northeast and east brought lots of sediment (sand and mud) into the coastal area and because the land area was slowly sinking, this sediment was able to accumulate up into great thicknesses. Global sea level rises and falls driven by remote processes of sea floor spreading and Antarctic glaciation influenced the character of the sediment, shifting environments landward (rise) or seaward (fall). With each shift in environments, the architecture of the sediment changed, as sand bars gave way to lagoons, which in turn were overlain by beach deposits.

Each cycle of sea level rise and fall generated three basic types of sequences in the John Henry Member: (1) tabular shoaling upward marine sequences (offshore); (2) wedge shaped bodies thinned basinward and landward respectively; and (3) lagoonal shales overlain by regressive coals. The interplay between subsidence (basin sinking), sediment supply, and sea level were the primary controls on which of these three types of sequences formed.

Facies control on sandstone composition (and influence of statistical methods on interpretations) in the John Henry Member, Straight Cliffs Formation, Southern Utah, USA

Authors:
Jessica L. Allen and
Cari L. Johnson

Sedimentary rock composition analysis has become a good tool as scientists seek to reconstruct the paleoenvironments of the paleontologically-rich formations within Grand Staircase-Escalante National Monument. Understanding the interplay of ancient climates, with the factors of the rock's parent materials and the processes that formed it, including changes in sea level through time, assists in better dating of formations, and predicting paleontological or mineral resources.

The authors used statistical methods to analyze the mineral components of sandstone samples from each of the characteristic rock types (facies) in two depositional environments in the John Henry Member. Elements of these studies can indicate whether the minerals were of marine origin, or were transported or sorted by geological or climatological forces, and the topographic position of a given sample as it became rock (i.e., a certain rock was deposited in the mouth of an ancient river channel). In this case, the John Henry Member sandstone reflects changes that occurred as the sea level of the Western Interior Seaway decreased, rather than obtaining its sediment from a different source.

Geology

Authors:
Brenda Beitler Bowen, Brigette A. Martini, Marjorie A. Chan, and William T. Parry

Reflectance spectroscopic mapping of diagenetic heterogeneities and fluid-flow pathways in the Jurassic Navajo Sandstone

Diagenetic geochemical processes can be uncovered by the emerging technology of reflectance spectroscopic mapping to evaluate historic episodes of fluid flow through sedimentary reservoirs in Navajo sandstone, in addition to resource management ramifications that result by having the potential to predict groundwater and hydrocarbon movement pathways. Spectral reflectance signatures can allow small-scale (tens of meters to kilometers) diagnostic evaluation of the heterogeneity of aeolian sandstone reservoirs and the range of their mineralogical composition.

The authors studied the East Kaibab monocline (a part of which is the formation called the Cockscomb), the White Cliffs of the Grand Staircase, and Calf Creek within the Grand Staircase-Escalante National Monument using this technique to better pinpoint the timing of paleohistoric fluid-flow events. Potential ramifications go beyond mapping subsurface reservoir rocks on a regional scale as this technology may be used in remote-sensing on Mars to elucidate sediment diagenetic systems indicated by the presence of hematite concretions.

Authors:
Marjorie A. Chan, Clark M. Johnson, Brian L. Beard, John R. Bowman, and W.T. Parry

Iron isotopes constrain the pathways and formation mechanisms of terrestrial oxide concretions: A tool for tracing iron cycling on Mars?

Using bleached and unbleached rock samples of regional sources of concretions from Navajo and Entrada Sandstone, including five from Grand Staircase-Escalante National Monument, iron isotope geochemical analyses were used to determine whether the Utah concretions were possible analogs to the hematite blueberries of Mars. Iron cycling can occur in precipitation, mobilization or reduction – iron oxides may even have a bacterial reduction process when iron is mobilized in Navajo Sandstone. By constraining the iron pathways and determining an open system, the authors hoped to find the diagenetic background of the Meridiani Planum concretions.

While most of the terrestrial concretions that were analyzed indicated virtually complete precipitation, which would not be likely for Mars' acidic conditions, two of them had partial precipitation explained by an open fluid-flow without a microbial influence that would enable the complimentary processes of oxidation and reduction: a potential tool that can be used on Mars' concretions.

Geology

Polygonal cracks in bedrock on Earth and Mars: Implications for weathering

Authors:
Marjorie A. Chan, W. Adolph Yonkee, Dennis I. Netoff, Winston M. Seiler, and Richard L. Ford

Garnering information from accessible, and apparently similar, formations on Earth's surface can ascribe valuable insight for past processes that may have occurred on Mars under alternate conditions from those that now exist. Establishing weathering on similar Martian surfaces may indicate past, and potentially subsurface, water. Pachydermal or polygonally-cracked sandstone features of roughly a meter or less on the surface of Navajo Sandstone within the Grand Staircase-Escalante National Monument had several shared characteristics with images of the Burns formation at Meridiani Planum that were transmitted by the Mars Exploration Rover Opportunity.

Interestingly, Navajo Sandstone exhibited case-hardening that could be attributed to two different mechanisms – one of which would be from microbial secretions. As case-hardening is a trait that may contribute to crack production, this may have the potential to indicate microbial life on Mars. The terrestrial cracking features cut across strata, are shallow in depth and are not present in fresh rock spalling from cliff faces but exhibit tensile failure properties from weathering, further indicating that weathering could also be the cause of the polygonal cracks on Mars.

Sediment Delivery to the Cordilleran Foreland Basin: Insights from U-Pb ages of Detrital Zircons in Upper Jurassic and Cretaceous Strata of the Colorado Plateau

Authors:
William R. Dickinson and George E. Gehrels

The derivation of the source of materials composing the fluvial and fluviodeltaic Upper Jurassic and Cretaceous strata across the Colorado Plateau, and locally exhibited within the Grand Staircase-Escalante National Monument, is important and may be determined when paleocurrent indicators of sediment delivery are borne out in the ages provided by detrital zircon samples from these sandstones.

Alternate longitudinal or transverse sediment transport modes to the foreland basin running along the Sevier thrust belt were tested and the zircon grains provided evidence that these aeoloian Jurassic sand deposits are attributable to Precambrian and Paleozoic recycling from the Mogollon highlands, as well as the Sevier thrust belt. The authors cautioned that the erosional thrust belt sand volume is not necessarily "balanced through time" with sediment volume deposited within the foreland basin, which may have been augmented by deposition from afar.

Geology

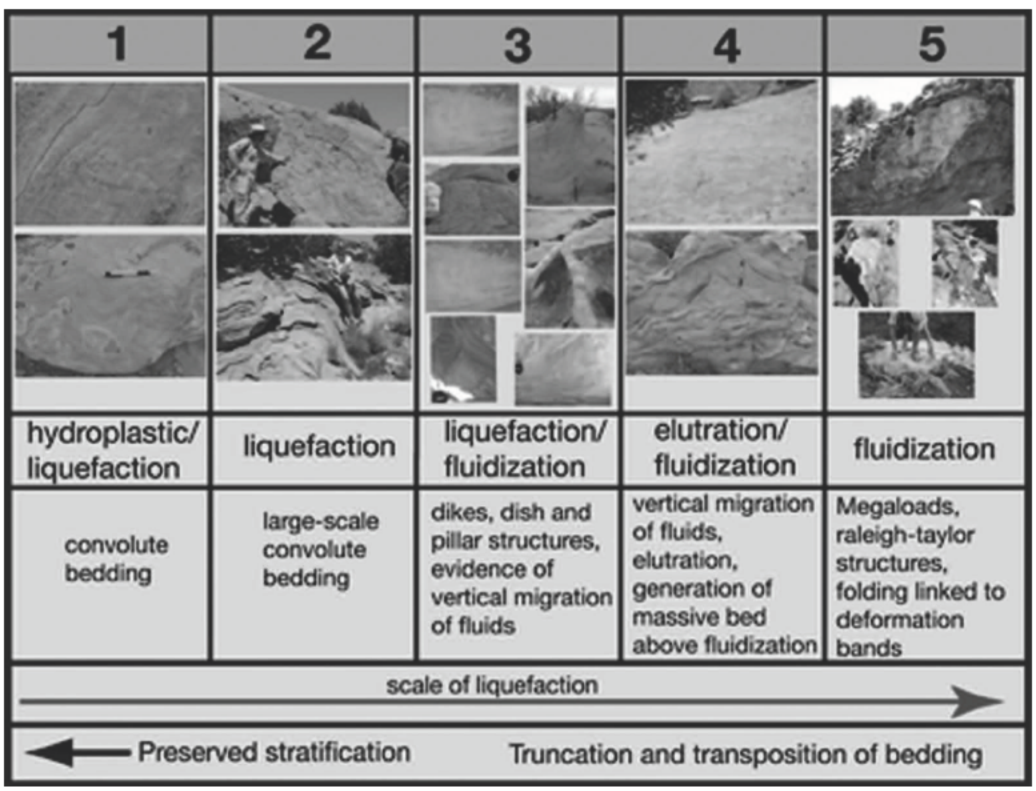
Insights into syndepositional fault movement in a foreland basin; trends in seismites of the Upper Cretaceous,Wahweap Formation, Kaiparowits Basin, Utah, USA

Authors:
Hannah L. Hilbert-Wolf, Edward L. Simpson, Wendy S. Simpson, Sarah E. Tindall, and Michael C. Wizevich

Geology

The Upper Cretaceous Wahweap Formation accumulated in the active Cordilleran foreland basin of Utah. Soft-sediment deformation structures are abundant in the capping sandstone member of the Wahweap Formation. By comparing these with well-established criteria, a seismogenic, earthquake, origin was determined for the majority of structures, which places these soft-sediment deformation features in a class of sedimentary features referred to as seismites.

Contour maps generated from the semi-quantitative analysis indicate a decrease in overall intensity from northwest to southeast in the upper and lower seismic zones and in sandstone within 5 m stratigraphically of the contact between the upper and capping sandstone members. In addition, cumulative seismite fold orientations support a west-northwest direction towards regional epicenters and indicated location of the earthquakes. Isoseismal maps are used to distinguish the influence of intrabasinal normal faulting from those of regional orogenic thrusting. Thus, this study demonstrates the utility of mapping seismites to separate the importance of regional vs. local tectonic activity influencing foreland basin sedimentation by identifying patterns that delineating paleoepicenters associated with specific local intrabasinal normal faults vs. regional trends in soft-sediment deformation related to Sevier belt earthquakes.



Facies Associations, Paleoenvironment, and Base-level Changes in the Upper Cretaceous Wahweap Formation, Utah, USA

Authors:
Zubair A. Jinnah, and Eric M. Roberts

The environment of deposition of sediment in the Wahweap Formation was examined in this study, and it was found that the lower three members (lower, middle, and upper), which consist of interbedded mudrock and sandstone, were deposited by river channels, swamps, and levees influenced by rises and falls in sea level. These sea level changes occurred at a similar time throughout the Western Interior Basin. The greatest marine incursion, at the contact between the middle and upper members, caused estuaries to develop in part of what is now the Kaiparowits Plateau.

The uppermost member in the Wahweap Formation, the capping sandstone, was found to be different from the other members in that the tectonic uplift of land, due to activity in the adjacent Sevier mountain belt, had a major effect on river systems when this member was deposited. This uplift resulted in less space for sediment to accumulate, and resulted in the capping sandstone having more sandstone, and less mudrock, than the lower part of the Wahweap Formation, as well as different mineral composition in the sandstones. River channels are well preserved in the capping sandstone, but there are very few swamp and levee deposits.

New ^{40}Ar-^{39}Ar and detrital zircon U-Pb ages for the Upper Cretaceous Wahweap and Kaiparowits formations on the Kaiparowits Plateau, Utah: implications for regional correlation, provenance, and biostratigraphy

Authors:
Zubair A. Jinnah, Eric M. Roberts, Alan L. Deino, Joseph S. Larsen, Paul K. Link, and C. Mark Fanning

Within the virtually-continuous span of Upper Cretaceous-Paleogene strata, this study used detrital zircon and bentonitic ^{40}Ar-^{39}Ar to further constrain the age and derivation of the Wahweap and Kaiparowits formations of Grand Staircase-Escalante National Monument. A better grasp of the timespan represented by these formations will also assist in the correlation of co-evolving fauna to the distinctive fauna that is emerging through continuing paleontological discoveries of dinosaurs and mammals.

The provenance of the Upper Cretaceous Wahweap and Kaiparowits formations was poorly known, other than linkages of sediment sources to the Sevier belt and Mogollon orogeny. The detrital zircon samples indicated the sandstone owes its formation to the Mesozoic-era volcanoes located further south as well as stream systems associated with the Cordilleran magmatic arc. Faunal results indicated that the late Campanian age is confirmed, and that a recalibration of Judithian North American Land Mammal and Aquilan "ages" is warranted.

Geology

The footprints of ancient CO_2-driven flow systems: Ferrous carbonate concretions below bleached sandstone

Authors:
David B. Loope and
Richard M. Kettler

The authors explore answers for the mysterious formation of iron-oxide concretions beneath bleached Navajo Sandstone in much of southern Utah. An explanation for the movement of iron down section and down dip from sandstone that was originally red to its current white manifestation and how an oxidizing aquifer could occur below a sea of reducing water was needed. Accompanied by clear graphics and high-resolution photos of landforms and the interior of puzzling concretions, this research addresses many geological questions of even casual visitors to Grand Staircase-Escalante National Monument.

As a bonus, this research sheds light on a technique that may help determine the reason for the Colorado Plateau's uplift relative to its surroundings by using absolute dating of concretions across this geophysical province.

Follow the water: Connecting a CO_2 reservoir and bleached sandstone to iron-rich concretions in the Navajo Sandstone of south-central Utah, USA

Authors:
David B. Loope,
Richard M. Kettler,
and Karrie A.
Weber

Geology

The geologic genesis of iron-bleached sandstone cliffs in southern Utah and a linkage with locally abundant iron-oxide concretions with iron-poor centers is considered in this analysis of the hydrodynamics of the Escalante anticline. Modern-day drainages to the Colorado River point to a mechanism within the paleoaquifer that caused both the migration of petroleum and natural gas to the Upper Valley Field, plus the transport of iron to the southeast: accounting for the white, bleached Navajo Sandstone on the crest of the anticline compared to the rich, red formations downdip.

The chemistry of the paleoaquifer connects the movement of the precipitated iron in the CO_2 reservoir to the formation of the concretions once the groundwater was degassed and micro-aerophile colonization occurred. The authors envision possible extraterrestrial applications to Martian hematite "blueberries" as well as a methodology for finding planetary water flow patterns.

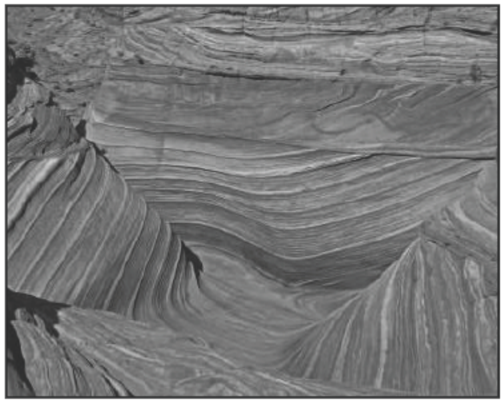
DOI-2019-06 02396

Wind Scour of Navajo Sandstone at the Wave (Central Colorado Plateau, USA)

Authors:
David B. Loope, Winston M. Seiler, Joseph A. Mason, and Marjorie A. Chan

While the Wave is a globally popular destination for tourism, few realize that the sandstone formation's sinuous sculpting has little to do with water, as its popular nickname seems to suggest. The authors credit two unacclaimed forces of nature: microbes and wind. This stealthy team has transformed lightly cemented dinosaur-era sand dunes into curvaceous, visually-appealing sandstone.

A thriving community of photosynthesizing microbes lies just under the surface of flat, tiny treads on the rock exposures, making them more resistant to sand-blasting winds than the "risers" which are vertical sandstone (measured in millimeters) layers between the protected treads. This tread & riser development also requires high-energy and low-angle wind-borne sand scouring that derives from scour pits and troughs upwind, and substantially upslope, of the Wave. This precious landscape has been formed by a fortuitous combination of geography, mechanical energy, geology, and biology.



The Wave in Vermillion Cliffs National Monument.

Aeolian activity at a giant sandstone weathering pit in arid south-central Utah

Authors:
Dennis I. Netoff and Marjorie A. Chan

Giant sandstone weathering pits, some of the largest on Earth, occur in many places on slickrock of the Navajo and Entrada sandstone formations within the Grand Staircase-Escalante National Monument and the surrounding region. The largest, known by many nicknames such as the Cosmic Navel, has developed near the summit of a dome and is considered to be an inselberg pit (German term for an "island mountain") with a 10 m pedestal in its center, which is formed from the same processes that resulted in Australia's Uluru Rock (formerly known as Ayers Rock). The Cosmic Navel also distinguishes itself by containing within it a large and active dune of strikingly different-colored sand (reddish-orange) from the pit's rock material (basically white).

The authors investigated the many forces that worked in concert to explain the inselberg pit's geomorphology. The initial ponding of runoff probably kick-started the weathering process on the fine-grained bedrock, combined with exceptional aridity and the erosional force of sand-filled prevailing winds, enhanced by concretion-undercutting and bacterial colonies that allowed rock fluting. The concretion-undercutting process may lend an explanation for Mars' "stalked blueberries" features.

Geology

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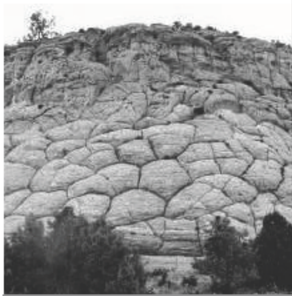
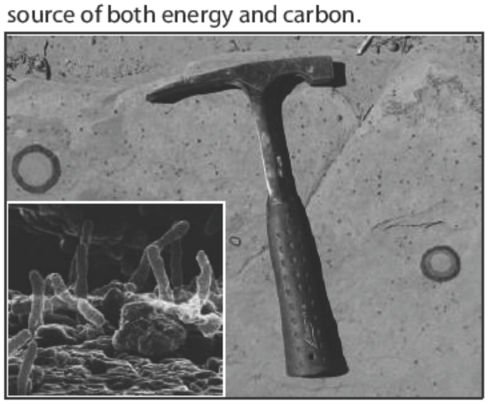


Microbial Origins of Iron-Oxide-Cemented, Secondary Concretions in the Jurassic Navajo Sandstone

Authors:
Geologists
David Loope,
Richard Kettler,
and Karrie Weber

In GSENM, the Navajo Sandstone forms high canyon walls along the Escalante and Paria Rivers and their tributaries. The Navajo was deposited near the western coast of the Supercontinent Pangea during the Early Jurassic by migrating desert dunes. Long after the loose dune deposits were buried by younger sediment and transformed into brittle sandstone, dissolved iron moved though the still-porous rock to many sites where concretions started to grow. These initial concretions were sphere- or platter-shaped and were solidly cemented throughout by an iron carbonate mineral, siderite ($FeCO_3$). Iron can be transported only in waters devoid of oxygen and siderite can crystallize only in such waters, so we think the Navajo was still deeply buried when these concretions formed. The Colorado Plateau, however, is now undergoing steady uplift. If siderite becomes exposed to oxygen-rich water, it is altered to iron oxide. The spherical and platter-like, iron-oxide concretions that we see in the Navajo today are secondary. They are the oxidized remains of first-generation (siderite) concretions that, as uplift and erosion brought them to the land surface, encountered groundwater with dissolved oxygen. Iron-oxidizing microbes colonized the concretions and "took charge" of the oxidation process, using the siderite as their source of both energy and carbon.



Rinded, iron oxide concretions in the Navajo . After their feast, microbes (inset) that consumed the siderite cement of the original concretion and left behind only a shell of iron oxide.

Large, plattered shaped concretions with iron oxide around perimeter, and along fractures. Microbes flourish at contracts between oxygenated water (outside) and O2 free water inside the concretion. The concretions and microbes responsible for the oxidation are younger than the host sandstone, and likely formed less than 2 million years ago.

When the spherical concretions weather out of sandstone outcrops, they accumulate in large numbers on the land surface. Although they superficially resemble meteorites, it is important to remember that they are entirely composed of cemented sandstone (and sandstone doesn't fall from the sky).

The microbes that we have found in the concretions are lithoautotrophs-- they got their energy by transferring an electron away from ferrous iron and moving it to an oxygen molecule. Like the microbes associated with the famous "Black Smokers" first discovered on the deep seafloor in 1978, the iron-oxidizers get all their energy from the Earth, not the Sun.

A good to see iron oxide concretion in GSENM along the trail to Upper Calf Creek Falls.

Geology

DOI-2019-06 02398

Facies architecture and depositional environments of the Upper Cretaceous Kaiparowits Formation, southern Utah

Author:
Eric M. Roberts

Although the Kaiparowits Formation within Grand Staircase-Escalante National Monument is a hot spot for Upper Cretaceous (Campanian) fossil discoveries, and has shown an extraordinary rate of sediment accumulation for the Western Interior Basin, its paleoenvironmental elements, such as its ancient geography and climate, have been poorly defined and are in need of facies analysis and interpretation. The aforementioned sedimentation rate, combined with the elevated heterogeneity of species and profusion of fossils of aquatic origin, indicate a corresponding paleoenvironment of a relatively wet, alluvial system with little topographical relief, similar to modern-day Louisiana.

The author identified fourteen lithofacies, with nine recurrent facies associations, with corresponding detailed descriptions, including paleoflow and paleontology. Based on this information, he determined that three informal units (lower, middle, and upper) compose the Kaiparowits Formation, of which the middle unit exhibits the best preservation of fossils. Regional tectonics partially accounted for a relatively quick subsidence of its basin (roughly taking two million years) which, in turn, contributed to the thickness of its strata.

Inconsistencies between Pangean reconstructions and basic climate controls

Authors:
Clinton M. Rowe,
David B. Loope,
Robert J. Oglesby,
Rob Van der Voo,
and Charles E.
Broadwater

The supercontinent Pangea dominated our planet from the Permian into the Jurassic. Paleomagnetic reconstructions have been used to estimate the latitudinal position of Pangea during this 100-million-year period. Atmospheric circulation, recorded by eolian sandstones in the southwestern United States, shows a broad sweep of northeasterly winds over their northernmost extent, curving to become northwesterly in the south.

This evidence is consistent with paleomagnetic reconstructions of the region straddling the equator in the Early Permian but is at odds with its northward movement to about 20°N by the Early Jurassic. At least one of the following scenarios must be true: The latitude based on paleomagnetism is incorrect; the interpretation of how winds shaped the dunes is mistaken; the basic climate controls in the Jurassic were different from those of today; or the paleogeographic reconstructions available are insufficient to adequately reproduce the wind fields responsible for dune formation.

Geology

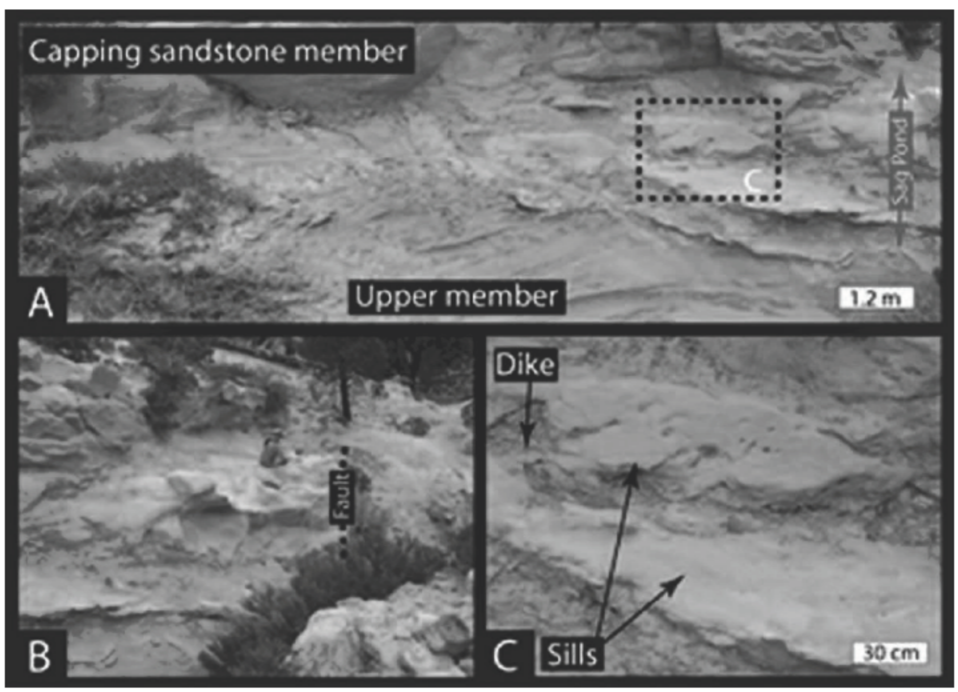
An Upper Cretaceous sag pond deposit: Implications for recognition of local seismicity and surface rupture along the Kaibab monocline, Utah

Authors:
E.L. Simpson, M.C. Wizevich, H.L. Hilbert-Wolf, S.E. Tindall, J.J. Bernard, and W.S. Simpson

Geology

In the Bull Flat area of Grand Staircase-Escalante National Monument sedimentological analysis of the tip line, front edge of the fault of a Late Cretaceous normal fault reveals that the fault was active during the deposition and preservation of a sag pond deposit. Sag pond deposits are where small ponds that develop adjacent to a fault collect sediment in a low area produced by fault movement. This deposit chronicles the activity on this ancient fault.

The sag pond sequence is located just below the contact between the upper and capping sandstone members of the Wahweap Formation, and it occurs within close association to other features of ancient earthquake generated structures (see figure). The sag pond deposit is a 2.2-m-thick succession of interbedded mudstones and siltstones intruded by earthquake-mobilized sandstone in the geometry of dikes and sills. At least two seismic events are required to produce the observed sag pond sequence. The initial earthquake event ruptured the surface, probably tilting the underlying strata, and produced the down-drop land surface for the sag pond. After infilling of the sag pond, a second seismogenic event mobilized sediment in the underlying sandstone and generated the dikes and sills that cross-cut the sag pond deposit. Subsequently, a minor stream channel scoured the sag pond deposit with flow parallel to the fault.

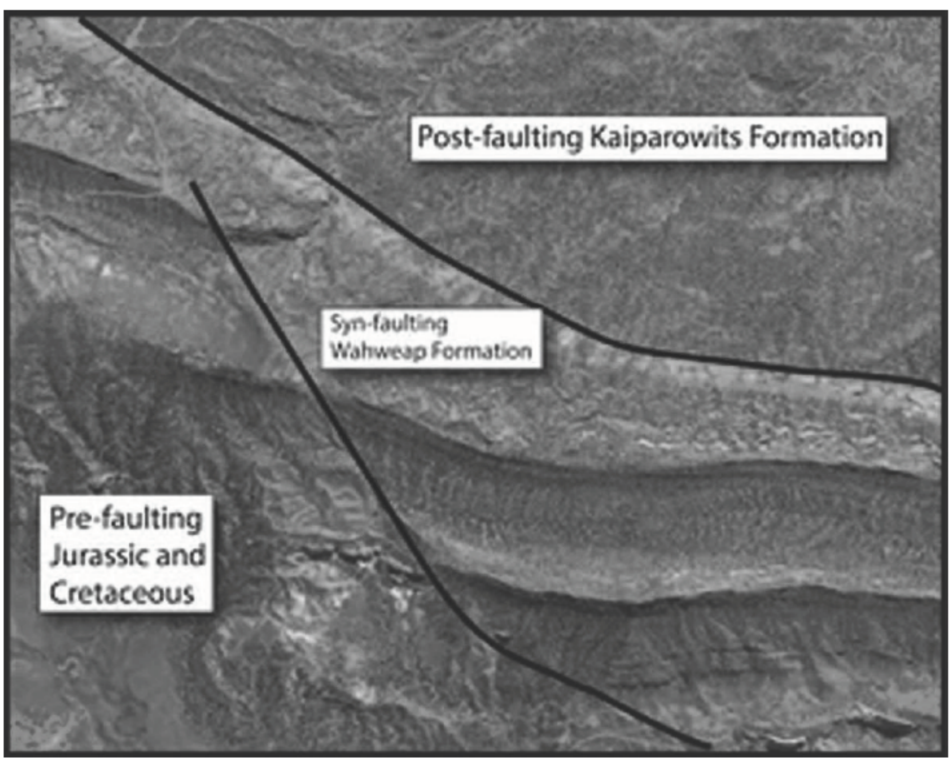


Sag pond field photographs. (A) Preserved sag pond geometry. (B) Sag pond deposit abutting the normal fault. (C) Earthquake mobilized sand forming dikes and sills.

Growth faults in the Kaiparowits Basin, Utah, pinpoint initial Laramide deformation in the western Colorado Plateau

Authors:
S.E. Tindall,
L.P. Storm, T.A.
Jenesky, and E.L.
Simpson

Growth faults develop and influence sedimentation patterns and are linked to deformation. Growth faults and their synorogenic sedimentary strata preserved in Upper Cretaceous units on the margin of the Kaiparowits Basin in southern Utah pinpoint the timing of onset of the Laramide orogeny in this region between 80 and 76 Ma. The newly identified curved normal faults, exposed in the steep limb of the East Kaibab monocline, disappear and moved parallel into shales and evaporites of the Jurassic Carmel Formation. Fault orientations and movement indicators yield strain directions consistent with fold-related extension parallel to the long axis of the growing East Kaibab monocline, or with development of a pull-apart basin at a bend in the trend of the fold. The association of the faults with the steep limb of a major basement-cored structure links them to the start of Laramide orogenic movement along the Kaibab Uplift. When combined with recent radiometric ages of rock units bracketing the fault-induced growth strata, these sedimentary and structural features narrowly define the onset of Laramide deformation in the western Colorado Plateau.



Google Earth view of the East Kaibab monocline with syn-depositional fault indicated. Note the thickening of the Wahweap Formation to the left (down drop side fault). When tectonic tilt is rotated the fault becomes a normal fault that constrains the onset of the Laramide orogeny in GSENM.

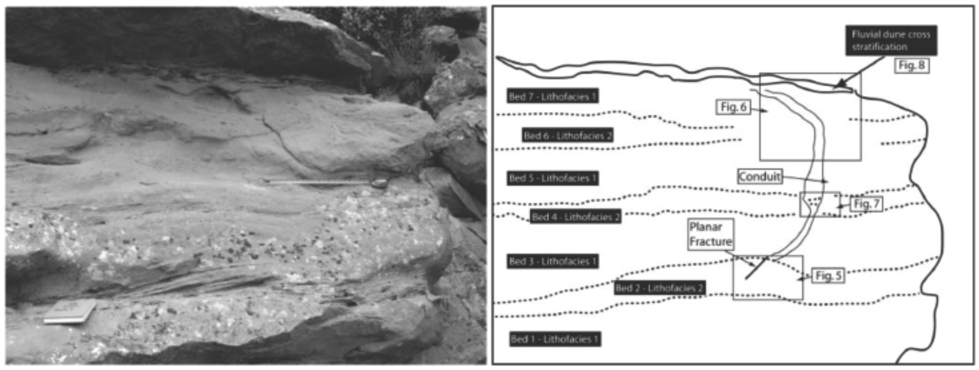
Geology

DOI-2019-06 02401

Implications of the internal plumbing of a Late Cretaceous sand blow: Grand Staircase-Escalante National Monument, Utah

Authors:
Edward L. Simpson, Hannah L. Hilbert-Wolf, Michael C. Wizevich, and Sarah E. Tindall.

Geology



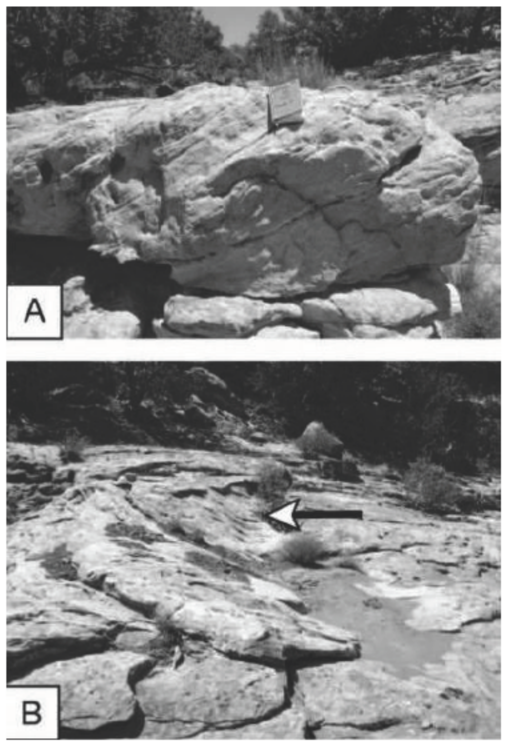
Preserved sand volcano. Figure taken from the paper.

A vertical cross-section through a well-preserved sand blow and associated sand volcano was discovered near the base of the Upper Cretaceous upper member of the Wahweap Formation. Preserved features within the feeder conduit (pipe) allowed reconstruction of the vertical flow and interpreted sand liquefaction generated by local seismogenic faulting. At the base the conduit is a dilation fracture that cross-cuts a low permeability sandstone seal. Above this seal the conduit widens and edges are harder to determine and the pipe contracts in diameter when it encounters a lower-permeability zone. The change in diameter and character of the pipe indicates that more fluid via lateral flow entered the flow. Within the pipe, subvertical stringers of granules indicate that vertical flow was strong enough to transport granules. Sands spew onto the surface forming a sand volcano cone. Internally the volcano sands are structureless. Modern sand volcanoes are commonly linked to high-magnitude seismic events. This feature is located close to active normal faults and indicates a high magnitude seismic event took place during its movement.

The interaction of aeolian and fluvial processes during deposition of the Upper Cretaceous capping sandstone member, Wahweap Formation, Kaiparowits Basin, Utah, U.S.A

Detailed examination of the Upper Cretaceous capping sandstone member of the Wahweap Formation in the Kaiparowits Basin, Utah reveals the presence of wind-blown layering. Deposition by wind processes is recognized and distinguished from water deposition by the presence of fine to coarse grain size grading, and wind-ripple stratification. The wind-related stratification in the Wahweap Formation is the first occurrence reported from Upper Cretaceous strata on the Colorado Plateau of the western U.S.A. Thin wind-reworked caps of river sandstones deposited within braided streams and as more extensive deposits of small-scale sand dunes that developed in geographically restricted dune fields. Wind reworking of river bars took place during low-stage flow and was possibly controlled by variation in seasonal discharge.

Prolonged periods of aridity led to increased sand supply permitting the development of dunes; dunes grew larger rapidly between the braided streams. These small dunes rarely developed steep fronts where sands could cascade down the fronts. The dunes were curved, probably barchans, amid and linked to the extensive braided stream systems. Based on modern examples, the resulting change in sand supply is related to a short-time interval climate shift to a more semi-arid/arid climate, and possibly yearly seasons. However, longer-term climate changes to semi-arid/arid may be indicated for the dune complex near the boundary with the overlying younger Kaiparowits Formation.



Small sand dune deposits in the capping sandstone member. (A) Inclined wind-ripple deposits. (Book for scale) (B) Exposed cross-beds illustrating the geometry of the small dunes.

Authors:
E.L. Simpson,
H.L. Hilbert-Wolf,
W.S. Simpson,
S. E. Tindall, J.J. Bernard, T.A. Jenesky, and M.C. Wizevich

Geology

Development of large-scale seismites in Upper Cretaceous fluvial sandstones in a fault-proximal setting

Authors:
Michael C. Wizevich, Edward L. Simpson, Hannah L. Hilbert-Wolf, and Sarah E. Tindall

Large-scale soft-sediment deformation structures occur within river sandstone bodies of the Upper Cretaceous Wahweap Formation in the Kaiparowits basin. These structures represent an exceptional example of meter-scale fault-proximal, seismogenic load structures in nearly homogenous sandstones. The load structures consist of two types: large-scale load casts and wedge-shaped load structures. Wedge-shaped load structures contain well-developed, medial cataclastic shear deformation bands. All load structures contain pervasive well-defined internal laminae, oriented parallel to the outside form of the load structures and asymptotic to deformation bands.

Both types of load structures formed because of an inverted density profile, earthquake-triggered liquefaction (a Rayleigh–Taylor instability) and growth of irregularities on the sandstone–sandstone erosional contact. Decimeter-scale wedge-shaped load structures on the edge of the large-scale load casts probably formed towards the end of a seismic event after the sediment dewatered and increased the frictional contact of grains enough to impart strength to the sands. Meter-scale wedge-shaped load structures were created as the tips of downward foundering sediments were driven into fractures, which widened incrementally with seismic pulsation. With each widening of the fracture, gravity and a suction effect would draw additional sediment into the fracture. Large-scale and wedge-shaped load structures, polyphase deformation and secondary laminae may characterize soft-sediment deformation in certain fault-proximal settings.

Geologist examining injection of copping sandstone sediments (lighter colored rock) into darker sediments.

Geology

DOI-2019-06 02404

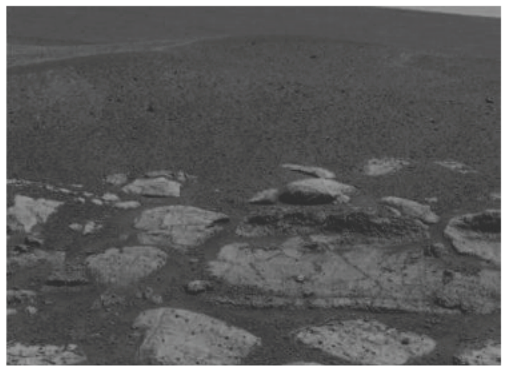
Ultrastructural Study of Iron Oxide Precipitates: Implications for the Search for Biosignatures in the Meridiani Hematite Concretions, Mars

Authors:
Virginia Souza-Egipsy, Jens Ormo, Brenda Beitler Bowen, Marjorie A. Chan, and Goro Komatsu

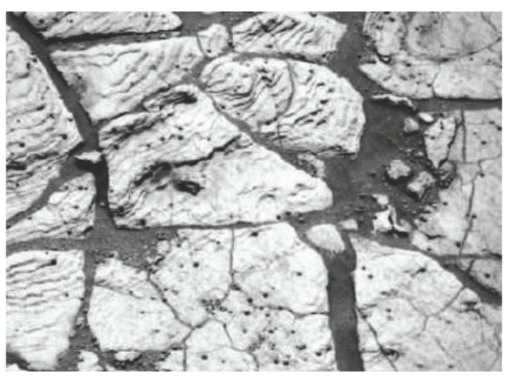
Geology

Comparing terrestrial analogs of Martian concretions may provide insight or evidence of life, just as conditions indicating weathering or residue from water were applied to remotely-sensed data. The Meridiani Planum was chosen for NASA's Mars Exploration Rover mission because indications were that hematite concretions were there to be found and its former environment potentially emulated an early Earth with biological conditions. The authors used modern iron oxide concretions with biofilms from Madrid, Spain, to compare to precipitates of iron and manganese oxide from Grand Staircase-Escalante National Monument (GSENM), which seemed most similar to those on Mars.

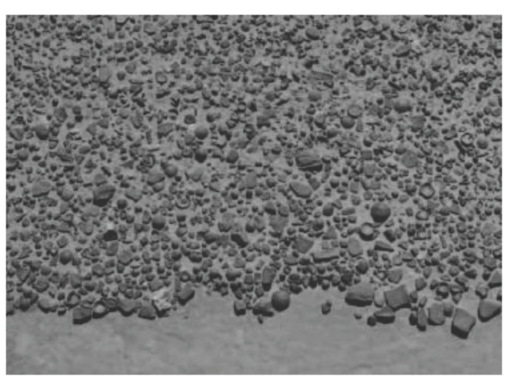
While there was no clear evidence of biosignatures in the GSENM concretions, the analysis was inconclusive for signs of life. It may be that the Utah marbles had inward growth given the results, but no biomediated, or microbial growth extending outward from a nucleus was observed.



Above: Hematite inclusions, also known as blueberries due to their blue hue in colorized images (seen below) released by NASA, were discovered by the Mars rover Opportunity at Meridiani Planum on the planet Mars.



Below: Iron concretions on GSENM



Plesiosaurs from the upper Cretaceous (Cenomanian-Turonian) Tropic Shale of southern Utah, Part 1: New Records of the Pliosaur *Brachauchenius lucasi*

Authors:
L. Barry Albright III,
David D. Gillette,
and Alan L. Titus

The deposits of the Tropic Shale Formation not only provide a comprehensive record of marine invertebrates, fish and sharks of Late Cretaceous age, but have also contributed significantly to our knowledge of marine reptiles from approximately 95 to 91 million years ago. Fairly recent discoveries include two specimens of the earliest known occurrence of a short-necked marine reptile, a group known as pliosaurids. *Brachauchenius lucasi* was formerly known only from the eastern margins of the Western Interior Seaway, a vast inland sea that divided North America into two land masses during the Cretaceous Period. This discovery expands not only the spatial but also the temporal range of this animal, suggesting that it was largely unaffected by the anoxic extinction event that occurred approximately 93.5 million years ago.

Plesiosaurs from the upper Cretaceous (Cenomanian-Turonian) Tropic Shale of southern Utah, Part 2: Polycotylidae

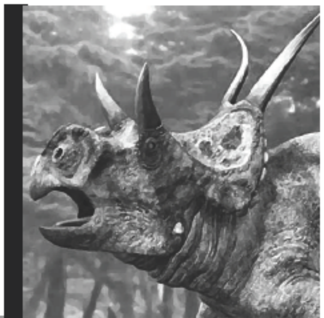
Authors:
L. Barry Albright III,
David D. Gillette,
and Alan L. Titus

While much of the ancient biological timeframes for the Tropic Shale within Grand Staircase-Escalante National Monument can be derived from the work that was previously performed on the Mancos Shale in the region, little was known of vertebrates when this area represented the western edges of the Cretaceous Western Interior Seaway. Fieldwork began to shed light on marine vertebrates, with the discovery of several types of short-necked plesiosaurs, mostly within the lower Turonian.

Cladistic analyses on the remains found to better characterize the distinctions between the short-necked plesiosaurs indicated that there were two types: pliosaurids (see Part 1 summary) and polycotylid plesiosauroids. Based on this work, two new subfamilies of polycotylids can be established. Further, the polycotylids can be divided into at least three types (known as taxa): 1. *Trinacromerum,* 2. *Eopolycotylus rankini* (a new genus and species), and 3. *Palmula quadratus.* Clearly the species diversity of the Upper Cretaceous was far richer than indications had been, and global marine extinctions during this time had little effect on these fauna.

Paleontology

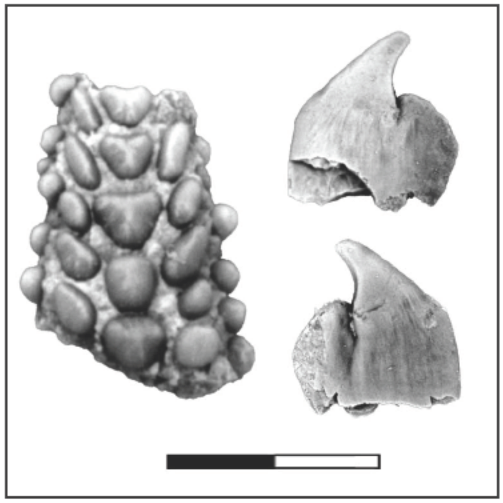
Fossil fish from the Grand Staircase Escalante National Monument



Author:
Don Brinkman

Complete skeletons of fish are rare in Utah's Late Cretaceous, but isolated elements are abundant in vertebrate microfossil localities. Both freshwater elasmobranchs (sharks) and bony fish are present. The elasmobranchs include a group of free-swimming sharks (hybodonts) that went extinct at the end of the Cretaceous, as well as bottom-dwelling elasmobranchs related to living guitarfish and carpet sharks. Bony fish include some that have their phylogenetic roots well down in the Mesozoic, such as the deep-bodied pycnodonts, the heavily scaled *Lepidotes*, and extinct relatives of the modern *Lepisosteus* (garfish) and *Amia* (bowfin). More derived teleosts are also present, some with close living relatives. These include members of the hiodontiforms (goldeye), elopomorphs (tapon), ostariophysans (possibly an early relative of the catfish), esocoids (pike), and acanthomorphs (spiny teleosts). Lungfish also occur early in the Late Cretaceous.

Since the Utah localities span approximately the first 20 million years of the Late Cretaceous, it is possible to trace changes in the fish assemblages. About 90 million years ago, a major faunal shift occurred. Pycnodonts and *Lepidotes,* which were dominant, became rare and gars and the large-bodied amiid Melvius first appear. Younger localities document a gradual increase in fish diversity.



Tooth-plate and isolated teeth from the deep bodied pycnodont *Coelodus* from the Naturita Formation. Scale bar equals 2 mm

Anterior end of the lower jaw of the early pike *Estesesox* from the Kaiparowits Formation. Scale bar equals 2 mm.

Paleontology

Fossil Turtles of the Kaiparowits Formation

Author:
Don Brinkman

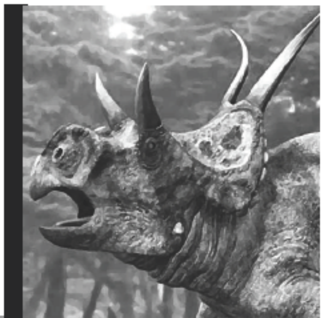
Fossil turtles are abundant in the Kaiparowits Formation, adding to our understanding of turtle diversity, taxonomic relationships, and biogeography during the Late Cretaceous. At least fourteen taxa are present, making this the most diverse late Campanian assemblage of turtles in North America. The most dominant groups are the Baenidae (a basal group of cryptodire turtles endemic to North America) and the Trioncyhidae (soft-shelled turtles). Less abundant, but of interest due to their subsequent evolutionary history, are the kinosternoid turtles, represented by a small, smooth-shelled taxon, possibly closely related to extant mud and musk turtles.

Latitudinal patterns are identified by comparing the Kaiparowits assemblage with contemporaneous assemblages from Alberta's Belly River Group and Montana's Judith River Formation. Six of the taxa present in the Kaiparowits Formation do not occur in formations of the same age in Montana or Alberta. These are *Compsemys, Denazinemys,* the small smooth-shelled kinosternid, and the trionychids *Helopanoplia* and *Derrisemys.* However, all but *Denazinemys* are present in Montana's Hell Creek Formation during the latest Maastrichtian. This is interpreted as a result of changes in distribution associated with the warmer climates of the latest Maastrichtian, with southern taxa moving farther north during this time of global warming.

Shell of the large baenid turtle *Neurankylus* from the Kaiparowits Formation

Paleontology

Late Cretaceous frogs from Grand Staircase-Escalante National Monument

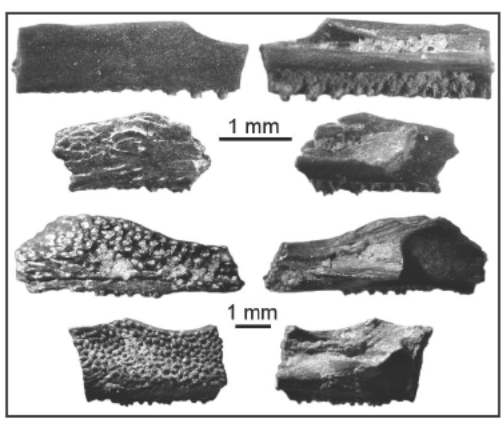


Authors:
James D. Gardner,
Zbyněk Roček,
Jeffrey G. Eaton,
and Richard L.
Cifelli

Frogs have a unique body plan (i.e., short trunk, no tail, modified pelvis, and elongate and muscular hind limbs) specialized for jumping and swimming. Thanks to their many distinctive skeletal features and tendency to live in environments favorable for preservation, frog remains are commonly identified in the fossil record. That record encompasses most continents and dates back about 250 million years to the earliest Triassic. The documented North American record for frogs extends from the Early Jurassic (ca. 185 million years ago) to the present.

Frogs arose during the early Mesozoic, lived alongside the dinosaurs, and today are the most successful and recognizable of living amphibians. Photo credit Sue Sabrowski.

Fossil frog bones are known from dozens of late Cenomanian to late Campanian age (ca. 95 to 70 million years ago) localities in southern Utah, including GSENM. Although those bones are isolated and often broken, they nonetheless provide insights into the evolution and diversity of frogs during the Late Cretaceous in western North America (Roček et al. 2010, 2012, 2013). Based on the number and variety of bones recovered from many localities, it is clear that frogs were locally abundant and that multiple taxa were present (Fig. 2); similar patterns are seen for modern frog faunas living in favorable environments. One interesting, but as yet unexplained, trend in the Utah collections is that smaller-sized frog bones dominated through much of the Late Cretaceous, with larger bones (from frogs about 2 inches and bigger) appearing only in the late Campanian.



Four maxillary morphs (upper jaw bones) hint at the diverse frog fauna ca. 72 million years ago in GSENM. Adapted from Rocek et al. (2013).

Paleontology

DOI-2019-06 02409

Evidence for high taxonomic and morphologic tyrannosauroid diversity in the Late Cretaceous (Late Campanian) of the American Southwest and a new short-skulled tyrannosaurid from the Kaiparowits formation of Utah

Authors:
Thomas D. Carr, Thomas E. Williamson, Brooks B. Britt, and Ken Stadtman

Until recently, the tyrannosaurid record for the Campanian of the Late Cretaceous (≈ 84 to 72 million years ago) in the southwestern United States was relatively scant, with only one representative from New Mexico. Tyrannosaurids, as apex predators, were important components of the paleo-ecosystem, and their lineage culminated in the universally known *Tyrannosaurus rex*, the largest and youngest member of its kind. The discovery of a new tyrannosaurid from the Kaiparowits Formation of Grand Staircase-Escalante National Monument sheds new light on the tyrannosaurid diversity of the Campanian. *Teratophoneus currei* is morphologically unusual. For example, unlike its contemporaries from New Mexico and the Northern Rocky Mountain Region, the animal is characterized by a deep, short skull. This demonstrates that tyrannosaur diversity was relatively high, and suggests that their skull morphology was driven by environmental conditions (endemicity).

Authors:
T.A. Gates, S.D. Sampson, L.E. Zanno, E.M. Roberts, J.G. Eaton, R.L. Nydam, J.H. Hutchison, J.A. Smith, M.A. Loewen, and M.A. Getty

Paleontology

Biogeography of terrestrial and freshwater vertebrates from the late Cretaceous (Campanian) Western Interior of North America

Extensive work in several fossiliferous units of late Campanian age, including the Dinosaur Park, Judith River, Two Medicine, Kaiparowits, Fruitland/Kirtland, and Aguja formations, has greatly increased understanding of Western Interior Basin (WIB) vertebrate faunas and their chronostratigraphic relationships. Here updated and greatly expanded faunal and chronostratigraphic datasets are utilized to undertake an extensive biogeographic analysis of these six terrestrial fossiliferous formations within the WIB of North America. Quantitative biogeographic comparisons of the formations and their constituent faunas are conducted using four statistical methods: Analysis of Similarity, Q-mode cluster analysis, Parsimony Analysis of Endemicity, and Correspondence Analysis.

The results of this study provide strong support for highly divergent faunas in northern and southern regions of the WIB, with a latitudinal faunal gradient as an interface. Yet the nature of the interface between these faunas remains unclear, with possibilities including: 1) two or more discrete provinces separated by a zone (or zones) of faunal mixing; and 2) a continuous latitudinal gradient or cline, with no discrete zones of endemism. Lacking evidence of any physiographic barrier to north–south dispersal, climatic variation within the WIB is regarded as the most likely explanation for the overarching biogeographic patterns observed for late Campanian vertebrate taxa.

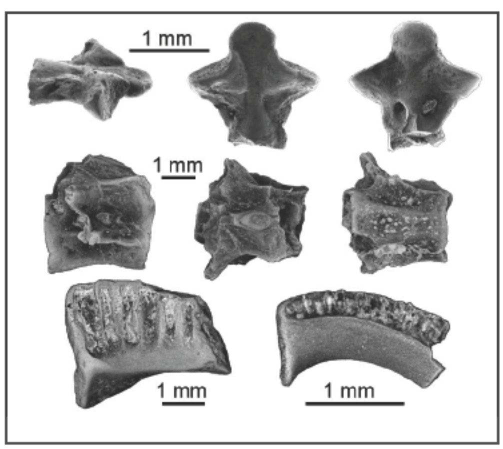
Late Cretaceous salamanders from Grand Staircase-Escalante National Monument

Authors:
James D. Gardner, Jeffrey G. Eaton, and Richard L. Cifelli

Salamanders are one of three living amphibian groups. They occur primarily in the Northern Hemisphere and have a global fossil record extending back to the Middle Jurassic. In containing over half of the world's known species and nearly all of its families, North America is an important continent for salamanders. The Late Cretaceous (ca. 100 to 66 million years ago) is an intriguing interval in salamander evolution, when a variety of extinct families coexisted with the first representatives of some living families.

A generalized tetrapod body, consisting of an elongate trunk and tail and similarly-sized front and hind limbs. Photo courtesy of Samantha Haddon.

Much of what we know about North American salamanders during the Late Cretaceous is founded on isolated bones, mainly vertebrae and jaws, collected from localities of late Cenomanian to late Campanian age (ca. 95 to 70 million years ago) in southern Utah (Gardner et al. 2013). That record is globally significant, because few other places in the world have yielded salamander fossils of comparable age. Fossils from GSENM and other areas in southern Utah document the oldest occurrences on the continent for the extinct salamander families Batrachosauroididae and Scapherpetontidae and for the still-living Sirenidae, and hint at the presence of other distinctive, but as yet unidentifiable taxa. Collectively those fossils indicate that salamanders were an important part of ecosystems during that time and that the group was rapidly evolving and diversifying through the Cretaceous.



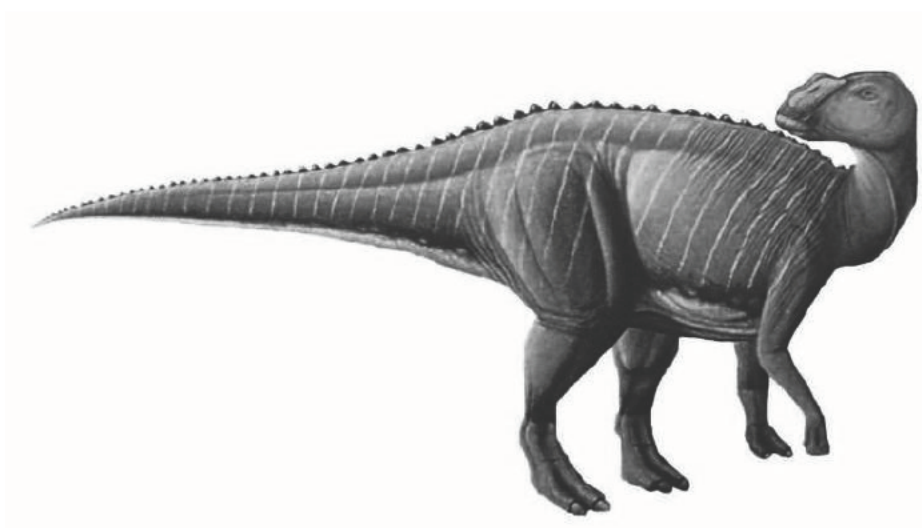
Salamander atlas (top), trunk (middle) vertebra, and lower jaws (bottom) from ca. 95 million year-old rocks in GSENM. Images courtesy of Indiana University Press.

A new species of Gryposaurus (Dinosauria: Hadrosauridae) from the late Campanian Kaiparowits Formation, southern Utah, USA

Authors:
Terry A. Gates and
Scott D. Sampson

The Kaiparowits Formation within Grand Staircase-Escalante National Monument has been shown to be contemporaneous with the Dinosaur Park Formation in Alberta, Canada, where *Gryposaurus notabilis* and *Gryposaurus incurvimanus* are found. At the time of the Kaiparowits' deposition, the paleoenvironment was similar to that of modern-day Louisiana swamps where conditions were well-suited for macrofossil preservation and have been rich sources of hadrosaurid fossils.

This new species of Gryposaurus, *Gryposaurus monumentensis*, is represented by an extremely robust, and mostly complete, though half-articulated, skull which indicated the need for a new taxon and a revision of its phylogeny, in addition to its considerable geographical and biological significance. Evolutionarily successful, the Gryposaurus genus not only spanned a time of five million years, but its incredibly diverse species roamed from the most southern manifestation here – as represented in the species *Gryposaurus monumentensis* - in the southwestern United States, all the way into Canada, over 2000 km. These dinosaurs roamed a broader expanse than nearly any other Campanian genera.



Artist Larry Felder's illustration of what *Gryposaurus monumentensis* may have looked like in life.

Paleontology

DOI-2019-06 02412

FOIA001:01697684

New unadorned hadrosaurine hadrosaurid (Dinosauria, Ornithopoda) from the Campanian of North America

This description of a new, duck-like billed hadrosaurid dinosaur, named *Acristavus gagslarsoni*, is based primarily on characteristics of its cranial frontal, postorbital and dentary morphology recovered nearly simultaneously in 2 western U.S. locations, including the Grand Staircase-Escalante National Monument. However, *Acristavus* exhibits no cranial ornamentation, a trait it shares only with *Edmontosaurus*. Other postcranial elements, including the pubis, were found and are clearly hadrosaurine.

The new taxon shows a clear relationship, based on braincase characteristics, to *Maiasaura* and *Brachylophosaurus* within its clade and shortens the temporal distance between the Campanian hadrosaurid and the Turonian's last non-hadrosaurid iguanadontian, hinting that the Coniacian Stage was the origin of these hadrosaurids.

Authors:
Terry A. Gates,
John R. Horner,
Rebecca R. Hanna,
and C. Riley Nelson

Dinosaur Tectonics: A Structural Analysis of Theropod Undertracks with a Reconstruction of Theropod Walking Dynamics

Authors:
Ole Graversen,
Jesper Milan, and
David B. Loope

The fossilized undertracks resulting from a dinosaur walking, found within the Middle Jurassic Entrada sandstone at the Twentymile Wash site within the Grand Staircase-Escalante National Monument, were analyzed for walking dynamics. A lucky set of circumstances resulting from a moistened sand dune that was then quickly cemented close to the surface helped capture these traces of a therapod while providing information on its speed and style of locomotion.

The authors applied the same concepts to the structural deformation of the sandstone on the remnants of the footprints that are used for crustal-scale tectonics and fault-related folding. Interestingly, the original sand was disturbed in an area three times the size of the dinosaur's foot. These walking dynamics provide information about the paleoenvironment existing at the time of the theropod, while its foot movements and weight distribution can be conveyed even after the initial set of tracks in a trackway have been weathered away. In some ways, this technique that can only be used on the displaced fossilized sediment of the deformation below and around dinosaur tracks can provide more information than the tracks themselves.

Paleontology

DOI-2019-06 02413

Therizinosaur—Mystery of the Sickle Claw Dinosaur

Author:
David D. Gillette

Paleontology

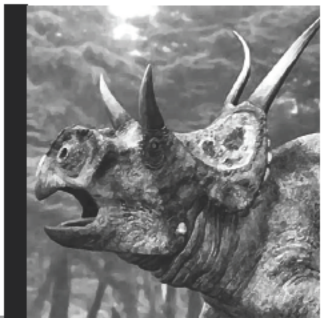
Artist Victor Leshyk's interpretation of a therizinosaur adrift at sea fending off potential marine predators.

The surprise discovery of a remarkable skeleton of a sickle-claw dinosaur in the Upper Cretaceous Tropic Shale in southern Utah led to excavation and ultimately to an exhibit by the same name as the title of this publication. *Plateau Magazine* is a companion to the exhibit, which was at the Museum of Northern Arizona from 2007 through 2009, and later at the Arizona Museum of Natural History in Mesa, Arizona, and finally at the Hayden Visitor Center at the Glen Canyon Dam.

The discovery was initially a puzzle because no sickle-claw dinosaurs, or "therizinosaurs," were known from North America. The Utah dinosaur was named *Nothronychus graffami,* or "Graffam's Sloth-Claw Dinosaur" in honor of its discoverer, Merle Graffam, of Big Water, Utah. The excavation yielded a nearly complete skeleton, which was cast and mounted in a bipedal pose about 13 feet (4 m) tall. It has a small head, tiny teeth, long slender neck, spindly forelegs with huge sickle-shaped claws, an enormous belly and rib cage, extremely wide hips, and very short tail. This issue of *Plateau* explores its perplexing array of anatomical features with the conclusion that this dinosaur was a theropod (carnivorous) dinosaur, but had made a major transition to feeding on plants, much like modern pandas, which are strictly herbivorous but came from an ancestry that includes modern dogs, bears, and cats.

Reconstructed skeleton of a therizinosaur at the Museum of Northern Arizona. Photograph by David D. Gillette

A gravid fossil turtle from the Upper Cretaceous (Campanian) Kaiparowits Formation, southern Utah



Authors:
Michael J. Knell,
Frankie D. Jackson,
Alan L. Titus, L.
Barry Albright III

A remarkably well-preserved fossil turtle shell was discovered in the Kaiparowits Formation in 2006 by a team of paleontologists near Horse Mountain in Grand Staircase-Escalante National Monument. The turtle belongs to the genus *Adocus*, which is recognized as a common semi-aquatic turtle of the mid to late Cretaceous Period, approximately 75 million years ago. Laboratory preparation of the turtle revealed skeletal material hidden within the inside of the turtle shell including portions of the pectoral girdle, neck vertebrae, limbs, and skull. Amongst these elements, however, was the surprising discovery of multiple preserved eggs.

Top view of fossil *Adocus* shell with exposed skeletal elements.

Fossil eggs are uncommon in general, but to find preserved eggs within the body of a vertebrate is extremely rare. Only a handful of gravid fossil turtles are known around the world, and this specimen exhibits perhaps the best skeletal preservation. Analysis of the egg structure under CT scanning microscope reveals the eggs are thinner than expected for comparable known fossil turtle eggs suggesting these eggs were still under-developed. The cause of death of the turtle, perhaps within a few weeks of nesting, remains unclear, but this female *Adocus* remains a rare find in vertebrate paleontology and reveals a great deal about ancient turtle reproductive physiology. The specimen remains partially prepared with exposed eggs and can be viewed on display at the Natural History Museum of Utah.

Identified skeletal elements with two partially exposed fossil eggs at bottom.

Paleontology

DOI-2019-06 02415

Shallow-water methane-seep faunas in the Cenomanian Western Interior Seaway: No evidence for onshore-offshore adaptations to deep-sea vents

Authors:
Steffen Kiel, Frank Wiese, and Alan L. Titus

After the deep-sea vents were explored about 40 years ago, it was clear that the unique species associated with them had unusual adaptations to survive beyond the limits of light, by subsisting on energy derived from sulfur-oxidizing bacteria. One of the explanations for this assemblage was that they may have evolved from near-shore, shallow-water methane-seeps where they could transition to deep-sea vents. In addition, as tiny aquatic crustaceans are more likely to colonize areas of warmer sea temperature, an ocean with very little difference in temperature from top to bottom would seem to encourage that behavior. The authors tested this hypothesis by finding paleontological evidence of a near-shore refuge that could have provided fauna to ocean vents thought to be wiped out by the massive aquatic extinction following the Oceanic Anoxic Event 2 (OAE 2). As the late Cenomanian period followed the OAE 2 and also experienced very warm temperatures, even at the ocean bottom, it was the perfect setup. However, this was not the case in the Cenomanian Tropic Shale mollusks: the fauna of on-shore and off-shore seeps were very different. This result holds true in our oceans today, even with oceans that are much colder at the bottom, and the shallow-water habitats do not provide species for the deep-sea vents.

An Introduction to Thunderbird Footprints at the Flag Point Pictograph-Tracksite: Preliminary Observations on Lower Jurassic Theropod Tracks from the Vermillion Cliffs Area, southwestern Utah

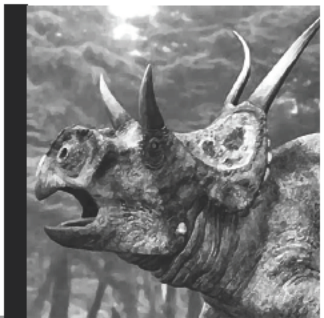
Authors:
Martin G. Lockley, Gerard D. Gierlinski, Alan L. Titus, and Barry Albright

The Lower Jurassic Kayenta Formation is widespread throughout southern Utah. These red mud- and sandstones were deposited in river systems, ephemeral lake settings (playas) and by the migration of large-scale sand dunes between approximately 200 and 176 million years ago. The upper part of the Kayenta Formation has produced numerous tracks and trackways, most of which are tridactyl and attributed to theropods, a group of mostly predatory, bi-pedal dinosaurs. The locally well-known Flag Point Track Site in the Vermillion Cliffs just east of Kanab in southeastern Utah is of particular interest, because it does not only feature medium-sized and large theropod tracks but is also associated with Native American (likely Fremont) pictographs that illustrate these three-toed tracks.

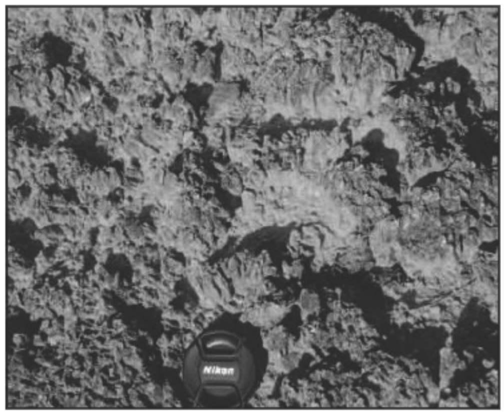
Paleontology

DOI-2019-06 02416

Toward the recognition of biological soil crusts in the rock record: key features from the study of modern and Cretaceous examples



Biological soil crusts (BSCs) are a ubiquitous and crucial component of modern semi-arid to arid ecosystems and probably were the first community type to colonize the Precambrian land surface. BSCs are complex symbioses of eubacteria, cyanobacteria, green algae, mosses, lichens, and fungi. BSCs, having adapted to intense UV radiation and drastic variations in precipitation and temperature were likely prevalent in terrestrial environments since the Precambrian, greater than 540 million years ago and are underreported in the rock record. This is probably due to the crusts' inconspicuous appearance and preservational taphonomy.



Example of a pinnacled modern biological soil crust developed on sediment shed from the Wahweap Formation, GSENM.

In order to improve the understanding of how BSCs may appear in sedimentary strata, this study reviews the biology, biologically produced structures, and morphological variation of modern BSCs using examples from Colorado Plateau BSC of southern Utah (Grand Staircase-Escalante National Monument). Sediment coring into modern BSC identified a variety of pedogenic features. Simple compaction experiments on the cores illustrate the taphonomic destruction of pedogenic features. In addition, comparison of the modern BSC features to those preserved in a Cretaceous BSC found in Utah demonstrate the utility of understanding the nature of the various stages of development of modern BSCs. These descriptions of potentially preserved expressions of BSCs should facilitate identification and separation of fossilized BSCs from other physical sedimentary structures.

Authors:
H. Fitzgerald Malenda, Edward L. Simpson, Michael C. Wizevich, Sarah E. Tindall

Paleontology

Crouching theropod and *Navahopus* sauropodomorph tracks from the Early Jurassic Navajo Sandstone of USA

Authors:
Jesper Milan,
David B. Loope,
and Richard G.
Bromley

Although essentially barren of body fossils, tetrapod tracks and trackways are relatively common in the Navajo Sandstone, thick dune deposits of Lower Jurassic age. Track makers include dinosaurs, crocodylomorphs and mammal-like reptiles, whose movements were recorded chiefly during wet periods. A 10-meter thick interval in northern Arizona's Coyote Butte area has yielded a particularly dense record of small theropod dinosaur tracks, a group of bipedal, mostly carnivorous dinosaurs.

Amongst those, but less common, are tracks of sauropodomorphs, bi-or quadrupedal, long-necked, herbivorous dinosaurs. Recently, a resting trace of a small theropod dinosaur revealed arm, leg and tail impressions, making it only the fourth discovery of its kind. The same site has yielded a sauropodomorph trackway that gave rise to a new genus of trace fossil.

Teiid-like Scincomorphan Lizards from the Late Cretaceous (Campanian) of Southern Utah

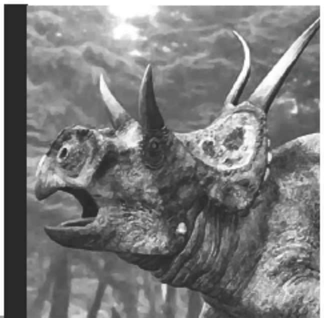
Authors:
Randall L. Nydam
and Gina E. Voci

The authors took a deeper look at the distribution and evolution of teiid-like scincomorphan lizards in western North America in the time of the Late Cretaceous, when all but one fossil recovered occurred west of the western shoreline of the Western Interior Seaway. These ancient teiid-like lizards are distinct from those of today, and none appear to have survived the Cretaceous-Tertiary extinction event.

The environment that these teiid-like lizards inhabited within what is now Grand Staircase-Escalante National Monument was very similar to large, river systems of today and the formation is generally composed of overbank flood deposits making the Kaiparowits Formation very thick and with a very homogenous species composition.

It does appear that the species diversified after the Western Interior Seaway developed; several new genera are described, as well as a new taxon. However, some teiid-like lizards have only been found within the Kaiparowits, and may be endemic to this region, as were some mammals of the time. There appears to be a latitudinal association with the species that are endemic.

Attributes of the wood-boring trace fossil *Asthenopodichnium* in the Late Cretaceous Wahweap Formation, Utah, USA



Authors:
K. Moran, H.L. Hilbert-Wolf, K. Golder, H.F. Malenda, C.J. Smith, L.P. Storm, E.L. Simpson, M.C. Wizevich, and S.E. Tindall

A common, easily recognizable, wood-boring trace fossil occurs in the Upper Cretaceous braided- and meandering-stream deposits of the upper and capping sandstone members of the Wahweap Formation in Grand Staircase-Escalante National Monument, Utah. Upon detailed examination, this trace warrants to be called *Asthenopodichnium* (Thenius, 1979). *Asthenopodichnium* is a scoop-shaped, pouch-like trace that is preserved as iron hydroxide rind casts of wood fragments and logs. The long axes of the scoops are typically aligned parallel or sub-parallel to the long axis of the preserved wood. In the upper and capping sandstone members, *Asthenopodichnium* characteristically occur in dense clusters in which pouches overlie one another, although they are found as isolated, individual traces and tight clusters of multiple individuals as well. The *Asthenopodichnium* trace maker is problematic but has been purported to be the possible product of mayfly nymphs developed in moving fresh water.

Examples of *Asthenopodichnium*. Note the lens cap for scale is 52 mm across.

Paleontology

The Occurrence of *Contogenys*-like lizards in the Late Cretaceous and Early Tertiary of the Western Interior of the USA

Authors:
Randall L. Nydam
and Brandon M.
Fitzpatrick

Earlier work has tentatively assigned *Contogenys sloani* fossils in the mid- and Late Cretaceous to the genus of Scincidae based on mandibles found in several localities. However, others have assigned it to Xantusiidae based on the morphology of its jaw and dentition. By phylogenetic analysis based on these same features and new specimens, including *Palaeoscincosaurus pharkidodon, Utahgenys gen.* and *U. evans*i found in Grand Staircase-Escalante National Monument, the Contogeniidae taxon nov. is actually most closely related to Xantusiidae, but is a new taxa that survived the Cretaceous/Tertiary (K/T) events and persisted through the middle Paleocene. New specimens were found in the Kaiparowits, Straight Cliffs and Dakota formations from the extraordinary Cenomanian through Campanian Cretaceous stratigraphy that is virtually continuous, and thus provides assurances of its dating.

The authors speculate that a xantusiid ghost lineage exists, with a high probability of a southern USA location, awaiting discovery and that the *Paracontongenys* lizard then will be ascribed as a xantusiid.

A new social insect nest from the Upper Cretaceous Kaiparowits Formation of southern Utah

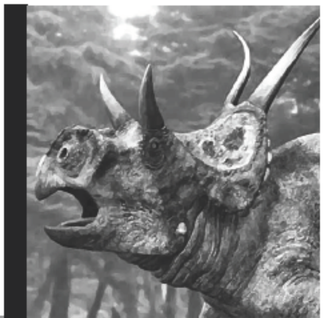
Authors:
Eric M. Roberts
and Leif Tapanila

The fossil-rich beds of the Upper Cretaceous Kaiparowits Formation in Grand Staircase-Escalante National Monument have yielded a new social insect nest: *Socialites tumulus.* This discovery of nine complex burrow networks in a depositional period provides interpretation of paleoenvironmental conditions such as climate and paleoecological knowledge to help reconstruction of ancient ecosystems. Although it is unclear whether the social insect was an ancestral form of ant or termite, the nest site indicated that it was preserved because of a flood that topped its channel banks, resulting in a partial evacuation.

Studies of fossilized ant nests are valuable because they are rare and poorly understood. This group of burrow networks most closely resembles the work of ants, but termites cannot be conclusively eliminated. The hope is that social insect evolution, behavior and the paleoenvironment they inhabited can be gleaned from trace fossils such as these. Not only are social insect nests rare in the Kaiparowits Formation, but if it was the nest of an unknown taxon of ant, it would be the earliest record of nest-building behavior.

Paleontology

Continental Insect Borings in Dinosaur Bone: Examples from the late Cretaceous of Madagascar and Utah



Authors:
Eric M. Roberts, Raymond R. Rogers, and Brady Z. Foreman

Vertebrate fossils may provide trace evidence of paleoecological conditions (based on insect climatic needs) and postmortem use as food or pupal chamber sites as evidenced by insect borings or bioglyphs. The authors use bone assemblages from Utah's Grand Staircase-Escalante National Monument and corresponding Upper Cretaceous continental strata to describe and name two new Ichnogenera and the corresponding two new Ichnospecies: *Cubiculum ornatus* and *Osteocallis mandibulus*.

During a review of four decades of research covering the Triassic to Pleistocene Period, nearly every continent has a record of fossil insect traces which can be grouped into five categories based on the morphology of the fossil marking. While little is directly known about the insects responsible for the bioglyphs other than the physical attributes necessary to make these bone borings, paleobehavioral insight may be postulated for these insects, such as evidence of bone-chip filled burrows within the dinosaur bone.

Paleontology

The Laramidia Project

Author:
Joe Sertich

Paleontology

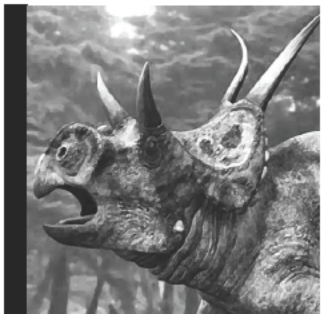
The Laramidia Project, a major collaborative effort led by the Denver Museum of Nature & Science, seeks to answer questions related to the tempo and mode of biotic change during a period of peak greenhouse ecosystem health. Between about 90 and 72 million years ago, the western half of North America, referred to as Laramidia, was isolated by rising sea levels and supported a diverse hothouse biota. A spectacular fossil record of this biota was preserved in sedimentary basins along the eastern margin of Laramidia, including some of the best preserved dinosaur ecosystems ever unearthed. In close collaboration with the BLM, the Natural History Museum of Utah, and the Raymond Alf Museum, research and fieldwork in the world-class exposures of Kaiparowits and Wahweap formations of Grand Staircase-Escalante National Monument has formed the core of the Laramidia Project.

Situated at a critical south-central point on Laramidia, the Kaiparowits and Wahweap ecosystems promise to help address questions related to continental biotic evolution, greenhouse expansion of the subtropics, and the origins of many modern groups of plants and animals. Work is multi-disciplinary, including floral, faunal, and geological investigations and has led to dramatic new discoveries of dinosaurs and associated vertebrates, fossil plants and forest structure, and ancient landscape structure and evolution.

Researchers from the Natural History Museum of Utah prepare a fossil for transport.

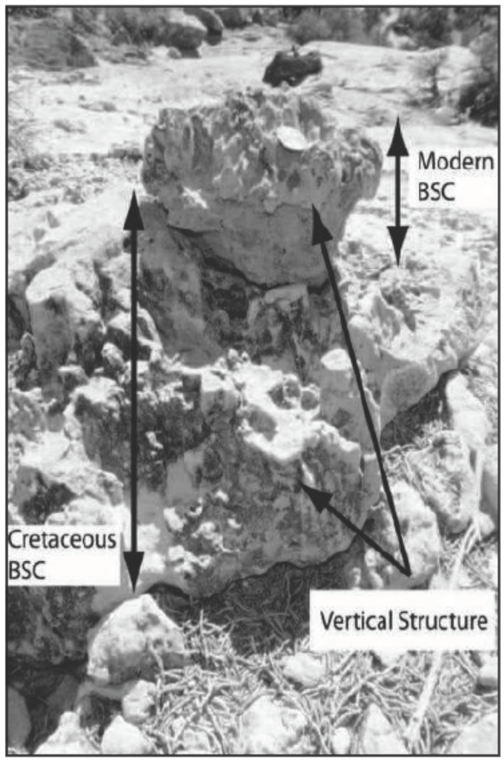
Crews utilize picks and power tools to remove an excavation site's overburden.

A preserved Late Cretaceous biological soil crust in the capping sandstone member, Wahweap Formation, Grand Staircase-Escalante National Monument, Utah: Paleoclimatic implications



Modern Colorado Plateau biological soil crusts (BSC) develop under semi-arid to arid conditions and are characterized by diverse communities of micro- and macro-organisms. The upper meter of the Upper Cretaceous capping sandstone member of the Wahweap Formation in Grand Staircase-Escalante National Monument, Utah contains an outcropping of an ancient BSC preserved in quartz sandstone. The interpretation of the capping sandstone BSC is based on comparisons with modern biological soil crust analogs, specifically similarities in morphological expression, sorted grain size variation, and proximity to associated eolianites.

This study reports on this rarely recognized type of paleosol, a biological soil crust and discusses paleoclimatic implications for a semi-arid to arid climate being present at the top.



Field photograph of a Cretaceous biological soil crust (bottom) with a modern biological soil crust on the top.

Authors:
W.S. Simpson,
E.L. Simpson,
M.C. Wizevich,
H.F. Malenda, H.L. Hilbert-Wolf, and
S.E. Tindall

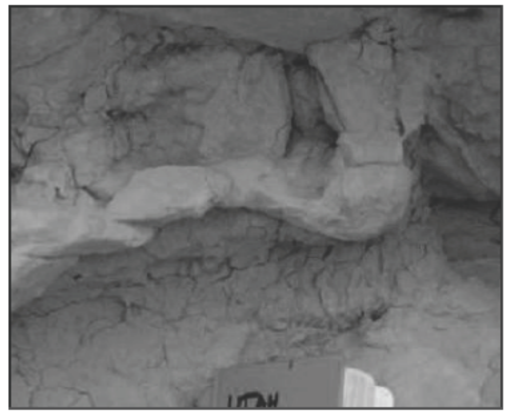
Paleontology

Predatory digging behavior by dinosaurs

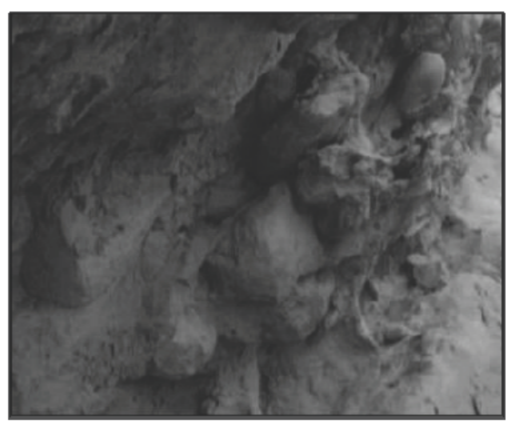
Authors:
Edward L. Simpson, Hannah L. Hilbert-Wolf, Michael C. Wizevich, Sarah E. Tindall, Ben R. Fasinski, Lauren P. Storm, and Mattathias D. Needle

Paleontology

A newly discovered Late Cretaceous trace fossil grouping (indirect evidence of an animal or plant being present in an area) of digging traces of maniraptoran theropod dinosaurs and mammalian den complexes indicates predator prey-interaction. Three distinct associated trace fossils occur within a floodplain siltstone-mudstone deposits in the Upper Cretaceous Wahweap Formation in southern Utah, United States. One trace fossil group recorded digging by a maniraptoran theropod dinosaur, possibly a dromeosaurid or troodontid. This is based on the preservation of a complete claw trace preserved in the edge of the structure and toe marks at the front. The other two traces are interpreted as mammalian den complexes. These traces have complex geometries including chambers, tunnels and ramps (seen in photos to the right). This cluster of trace fossils suggests that dinosaurs used excavation techniques to hunt and prey on mammals.

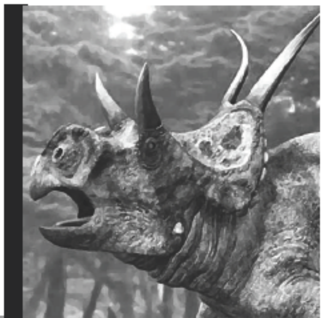


Burrow. Note chamber on the left and flared opening. Book for scale.



Burrow. Note chamber on the left.

A new North American therizinosaurid and the role of herbivory in predatory dinosaur evolution



Authors:
Lindsay Zanno,
David D. Gillette, L.
Barry Albright, and
Alan Lee Titus

Theropod dinosaurs used to be commonly associated with groups that are carnivorous and unequivocally predatory (as apparent in tyrannosaurids and dromaeosaurids). However, a group of theropod dinosaurs whose members were primarily omnivorous and herbivorous has recently come to the attention of paleontologists. Characterized by their long forelimbs, maniraptorians include, for example, modern birds (Avialae) and a group called Therizinosauria. A new species of therizinosaur, *Nothronychus graffami,* was found in Late Cretaceous rocks of southern Utah. The specimen was nearly complete and thus allowed for rigorous analysis of the evolutionary development of these theropods. The findings suggest that either herbivory is a primitive trait while carnivory is a more derived dietary specialization, or herbivory developed independently alongside carnivory.

Above: Paleo-artist Victor Leshyk's rendition of what *Nothronychus graffami* may have looked like in life. Below: The sickle like claws of therizinosaurus would have been an impressive defensive weapon.

Paleontology

DOI-2019-06 02425

Sedimentology and Paleontology of the Upper Cretaceous Wahweap Formation sag ponds adjacent to syndepositional normal faults, Grand Staircase-Escalante National Monument, Utah

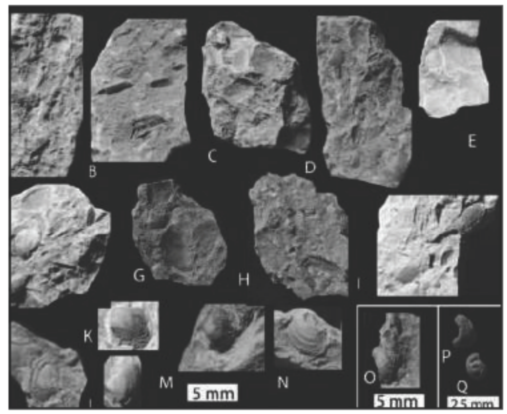
Authors:
E.L. Simpson, R. Koch, E.A. Heness, M.C. Wizevich, S.E. Tindall, H.L. Hilbert-Wolf, K. Golder, A.K. Steullet

Paleontology

During the development of the East Kaibab monocline, curved normal faulting related to outer arc bending influenced the sedimentation style of the Upper Cretaceous Wahweap Formation. The initiation of the Laramide Orogeny was therefore recorded in the sedimentary record of south-central Utah.

Evidence for this includes the preservation of sag ponds adjacent to two of the normal faults in our study area, which developed when fault movement created topographic features. Ancient sag-pond deposits are likely under-identified in the rock record. This study demonstrates their significance and potential for unraveling fault histories. The northern, younger, sag-pond deposit is located at the boundary between the upper and capping sandstone members of the Wahweap Formation, and consists of sandstone dikes and sills hosted in gray mudstones and siltstones with no discernible invertebrate fauna, but some small macerated flora.

The second southern sag-pond fill is located at the base of the upper member. The sag pond is older, larger in area, and contains a thicker deposit. In contrast to the northern sag-pond deposit siltstones and mud-stones are gray and structureless. Within the southern sag pond there are a series of fossil horizons consisting mainly of juvenile unionid bivalves, a lesser number of gastropods, and macerated plants. Comparison of the two preserved Upper Cretaceous sag-pond deposits suggests two distinct responses to fault movement, perhaps governed by fault kinematics, manifested in sedimentation style and type; the impact of faunal invertebrate invasion; and post-sedimentation deformation.



Freshwater fauna from upper member sag pond. A-N Unioniod bivalves. O-P Gastropods.

DOI-2019-06 02426

Southern Utah Oral History Project: A Record of Living with the Land the second decade

Author:
Marsha Holland

Social Sciences

While the land of Grand Staircase-Escalante National Monument (GSENM) is known for its unique beauty and rugged qualities, the people who helped settle the region and continue to sustain themselves here are as unique and rugged as the land itself. On this premise the Southern Utah Oral History Project began with an interest in preserving the cultural history of small towns in southern Utah that border GSENM. Besides preserving the area's cultural history, the project also shows how the landscape influenced human settlement. GSENM initially partnered with Utah Division of State History to record human activity and land use during the first half of the twentieth century in the region bordering the monument.

Former Utah Governor Mike Leavitt was interviewed by Marsha Holland as part of the Oral History Program on the creation of GSENM.

After a decade of collection, GSENM expanded the project to include interviews from people who were involved with the monument in the early days – from designation, planning and implementation to those who conducted the first research on the monument after it was designated. Added to this Monument History segment are interviews with entities that GSENM has partnered with over the years, such as Scenic Byway 12 Committee and Escalante River Watershed Partnership.

Since 1996, historians have gathered more than 300 interviews for this oral history collection which is now archived at Southern Utah University's Sherratt Library, Utah Division of State History Research Library and at Grand Staircase-Escalante National Monument Headquarters, Kanab.

Southern Paiute Nation tribal elder, Gevene Savala was also interviewed for the project.

Designation of the Grand Staircase-Escalante National Monument and the Impact on Trust

Authors:
Peggy Petrzelka, Sandra Marquart-Pyatt, and Michael Lacolucci

This paper describes the impacts of the Grand Staircase-Escalante National Monument (GSENM) designation based on survey data collected in Escalante, Utah, in 1996 and 2006. The analysis summarizes local reaction to the GSENM designation, examines the designation impacts on trust in federal agencies, and traces public opposition to national monument proposals back to 1938.

The authors compared responses from Escalante residents who participated in both surveys and identified a decline in "trust in the agencies to make good decisions" about land management.

Results show "views on the federal government's manner of monument designation in 1996 significantly predict trust in the Bureau of Land Management (BLM) in 2006." Those with positive feelings about the designation have higher trust in the BLM and those with negative feelings have lower levels of trust in the BLM.

This study suggests, "it may not be what the BLM is doing (or not doing) locally which influences trust in them; it is the actions by those at a more distant level of governance." The observation that seemed most significant was, "when people are left out of the decision making process, it gives them a great incentive to sabotage anything that comes out of that process."

Finding Common Ground: Moral Values and Cultural Identity in Early Conflict over the Grand Staircase-Escalante National Monument

Author:
Sarah Fleisher Trainor

Citing historical records, articles, studies, and personal interviews in Kanab, Escalante, Boulder, Cedar City, Pipe Springs, St. George, and Panguitch, Sarah F. Trainor provides insights to differing cultural and moral values represented in three major Grand Staircase-Escalante National Monument (GSENM) stakeholders—Native American Indians, Mormon pioneer descendants, and wilderness advocates.

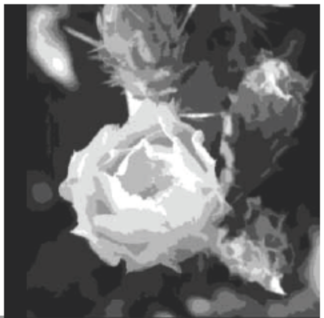
Contrasting values are at the heart of conflict over land and resource management. Native Paiute values convey a relationship with nature of respect and honor. Regarding GSENM, "Kaibab Paiute would like access to their traditional homeland and comanagement of resources, and they oppose resource damage or destruction."

Mormon communities introduced non-native species for economic benefit, altered landscapes to accommodate water distribution through reservoirs and irrigation canals to support farming and ranching, and saw themselves as "victims" of past conflicts involving federal entities and environmentalists.

Wilderness preservation advocates stress "ecosystem, scientific, intrinsic and aesthetic values" favoring an "untrammeled wilderness." By understanding the historical, cultural, and religious values between parties in conflict, groups can build trust, open communication, and find common ground.

Social Sciences

Addendum



AVIAN COMMUNITY RESPONSES TO MECHANICAL THINNING OF PINYON-JUNIPER WOODLAND AT GRAND STAIRCASE ESCALANTE NATIONAL MONUMENT, UTAH, USA

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ABSTRACT

In 2005-2006, we studied the responses of breeding birds to mechanical thinning of pinyon-juniper woodlands at Grand Staircase Escalante National Monument, Utah. The thinning in April 2006 removed a mean of 92% of the live trees from treatment plots. We found that two species (Gray Vireos and Brown-headed Cowbirds) were lost from the avian community following the thinning. Bird species characterized as pinyon-juniper specialists decreased in relative abundance in treatment areas and increased in control areas. Relative abundance of the shrub-nesting guild increased in mechanically-thinned areas and decreased in control areas. If the directions of change observed in our study continue over time, shrub-nesting birds may benefit at the expense of pinyon-juniper specialists. However, some species may exhibit a time lag in response, and further changes in community composition and abundance could result. It is important for managers to understand the implications for avian community structure, when thinning pinyon-juniper woodlands.

KEYWORDS: avian community dynamics, mechanical fuels reduction, pinyon-juniper woodlands, pinyon-juniper birds

INTRODUCTION

Pinyon (*Pinus* spp.) –juniper (*Juniperus* spp.) woodlands are distributed extensively across the Colorado Plateau, and are estimated to cover 24 to 40 million hectares in the Intermountain West (Samuels and Betancourt 1982). The distribution of these woodlands has expanded and contracted throughout history (Tausch 1999), and expansion is presently occurring at a high rate (Miller and Wigand 1994), but not throughout the entire range (Harris et al. 2003, Rowlands and Brian 2001). Potential catalysts to this rapid expansion are many and include fire suppression and livestock grazing (Baker 2006; Harris et al. 2003; Johnsen 1962; Miller and Rose 1999; West 1984), coupled with natural factors (Baker and Shinneman; Rowlands and Brian 2001) and climate change (Gray et al. 2006).

Land managers are increasingly implementing fuels reduction treatments in pinyon-juniper woodlands with the goals of habitat restoration and hazard fuels reduction. In the past, the tools of choice were fire and chaining to remove colonizing junipers and pinyon pines. Subsequent to those efforts, pinyon pines and junipers have reemerged in chained areas on sagebrush steppes and grasslands over the Colorado Plateau. Currently, managers are increasingly using hand cutting methods in place of chaining and prescribed fire.

More than 70 species of birds breed in pinyon-juniper woodlands, but breeding bird community composition varies considerably among individual woodlands (Balda 1987). Bird species identified as breeding solely in pinyon-juniper woodlands (obligates) include the Gray Flycatcher (*Empidonax wrightii*), Western Scrub-Jay (*Aphelocoma californica*), Juniper Titmouse (*Beolophus ridgwayi*) and Gray Vireo (*Vireo vicinior*) (Balda and Masters 1980). Bewick's Wren (*Thryomanes bewickii*), Blue-gray Gnatcatcher (*Polioptila caerulea*), and Black-throated Grey Warbler (*Dendroica nigrescens*) have been characterized as pinyon-juniper

specialists in the Intermountain West (Pavlacky and Anderson 2001). Avian communities respond to changes in vegetation structure as woodlands encroach on or retreat from sagebrush- or grass-dominated vegetation communities (Knick et al. 2005; Medin et al. 2000; Rosenstock and van Riper 2001).

The objectives of this study were to assess the effects of mechanical pinyon-juniper reduction on avian community dynamics within a sagebrush steppe. Our study tested the following hypotheses: (1) community composition after mechanical thinning ≠ composition before mechanical thinning (2) abundance of pinyon-juniper specialist species after mechanical thinning < abundance before mechanical thinning (3) abundance of shrub-dependent species after mechanical thinning ≥ abundance before mechanical thinning (4) number or degree of changes in presence or abundance of pinyon-juniper and shrub dependent species > number or degree of changes in presence or abundance of other species.

METHODS

Study Area

Grand Staircase Escalante National Monument (GSENM) is a 688,000ha unit in Southern Utah, administered by the Bureau of Land Management (BLM). The Ford Pasture Fuels Reduction

project area (hereafter called 'Ford Pasture') is in the southwest corner of the Monument, off roads 601 and 602 in Johnson Canyon, about 30 kilometers northeast of Kanab, Utah (Fig. 1). The climate is arid with the 34+ cm of annual precipitation falling in a bimodal pattern, with 51% between November and March, and the remainder falling throughout the other months.

Our study area (Ford Pasture) was at an elevation of 2,000m on a sagebrush (*Artemisia tridentata* Nutt.) steppe with scattered pinyon-juniper woodlands. Dominant trees are Utah juniper (*Juniperus osteosperma* Torr.) and two-needle pinyon-pine (*Pinus edulis* Engelm.), although these are distributed patchily in the relatively flat sagebrush-dominated areas. Small higher density pinyon-juniper woodlands are on the surrounding low hills. Tall shrub species include Gambel oak (*Quercus gambelii* Nutt.) and Utah serviceberry (*Amelanchier utahensis* Koehne). Rubber rabbitbrush (*Chrysothamnus nauseosus* Pall.) and occasional patches of sticky-leaved rabbitbrush (*Chrysothamnus viscidifloris* (Hook.) Nutt.) are scattered among Great Basin big sagebrush (*Artemisia tridentata* Nutt.). Herbaceous plants include daisies (*Erigeron* spp), lupines (*Lupinus* spp), and globe mallow (*Sphaeralcea ambigua* Gray), with the following grasses: crested wheatgrass (*Agropyron christatum* (L.) Gaertn.), needle-and-thread grass (*Stipa comata* Trin. and Rupra.), Indian ricegrass (*Orhyzopsis hymenoides* Roem. and Schult.), *Elymus* sp, cheatgrass (*Bromus tectorum* L.), and six-weeks fescue (*Festuca octaflora* Walt.).

Sampling Design

Grand Staircase Escalante National Monument personnel divided the 323ha Ford Pasture into four units, two of which were assigned to mechanical thinning by hand cutting (lop and drop – herein defined as trees cut and left where they fell) and two for controls. In 2005, prior to the mechanical-thinning treatment, we installed 20 bird count stations in Ford Pasture. In each of the treatment and control units, we navigated to randomly generated coordinates using Garmin

GPS 12 receivers (Garmin Ltd, North America), and installed rebar at that location to mark the point count station. We discarded all coordinates within 50m of a unit boundary, and maintained a minimum 200m between stations. To aid in accurate distance estimation, we tied colored flagging on vegetation to mark known distances from the point count station. We defined a 100m radius circle centered on each station as a bird plot.

Vegetation Sampling

Vegetation was measured on all plots in July and August 2005. Gambel oak was treated as a shrub, which is its common form on the study site. The mechanically-thinned units were cut with power saws April 10– 16, 2006. Downed trees were left in place where they fell. Snags and tall shrubs were not cut. We repeated vegetation measurements on all bird plots in the mechanically-thinned units during May and June 2006.

Our vegetation sampling design was based on the BBIRD Protocol (Martin et al. 1997). Here we discuss our departures from that protocol. From each bird count station, we measured the distance to the nearest juniper, the nearest pinyon, and the nearest tree if a third species was closer, in each of four directions (NE, SE, SW, NW). The nearest trees were found by walking in a spiral pattern from the point. Distances beyond 25m were measured with Garmin GPS 12 receivers. Additionally, we measured the distance from the station to the nearest shrub species in each quarter, and then identified that shrub species.

Four vegetation subplots were located 50m from the bird count station in each of the cardinal directions. We measured trees within a 15m radius, and shrubs within a 5m radius. We measured tree density by the number of individuals, shrub density by the number of stems. Diameter at breast height (DBH) was recorded only for single-stemmed trees, diameter at root

crown (DRC) for multi-stemmed trees. Diameter at stump height (ST), measured at 12" (30.5cm) above the ground (Bradshaw and Reveal 1943) was also recorded. All diameter measurements were made with a ruler held perpendicular to the trunk. For living junipers whose main trunk lay prone on the ground, with all new upward growth occurring in what were originally horizontal branches, we measured height of the tallest "branch." We measured the diameter of these trees at what we estimated to be 30.5cm along the main stem from the original root crown. For analysis, all diameter measurements were converted to diameter at root crown using the slope equation from regressions of DBH and ST on DRC. We determined tree maturity classes following Bradshaw and Reveal (1943). Due to the clumped distribution of trees at Ford Pasture, we used visual estimations of canopy cover in the vegetation subplots rather than spherical densiometer measurements. In order to standardize canopy cover estimates, a single person performed all measurements. In each vegetation plot, we estimated percent ground cover and percent cover of plants <50cm tall in a 1m x1m square quadrat. The quadrat was located by selecting a meter distance between 0 and 5, and an azimuth between 0 and 360 degrees, from a random numbers table. We used a frame of PVC pipe to delineate the quadrat.

Bird Sampling

We conducted bird counts at each station on five occasions during May and June of each year (2005 and 2006), using variable circular plots (Reynolds et al. 1980) truncated at 100m maximum radius. Surveying mechanically-thinned and control plots pre- and post-thinning allowed us to separate the effects of thinning from variation due to non-treatment factors, such as local weather conditions. Observers waited for one minute upon arriving at each station before recording detections. The identification and distance from the station were recorded for all birds

detected (visually or aurally) within the 100m radius bird plot over a period of 5 minutes. Observers used marker flagging and laser rangefinders to increase accuracy of distance estimation. We also noted any birds detected >100m distant, flying over, or between bird plots. Visits to each bird plot were generally about 1 week apart, between sunrise and 10 am. In 2005, two observers alternated visits to minimize observer bias. In 2006, one observer conducted all surveys. Observers were trained and tested in local bird identification and distance estimation at the beginning of the season. No counts were conducted during rain or high winds. Sampling order of plots was varied in order to minimize temporal bias.

Data Analysis

We performed all statistical analysis with JMP IN software (SAS Institute 2003), except where otherwise noted. Vegetation measurements were averaged across the four vegetation subplots to describe vegetation characteristics per plot. At each bird plot, we followed a plotless distance method to determine an index of aggregation ($A_1 = ((\Sigma d^2/d'^2)/n) - 0.5$), where d=distance to the nearest tree, d'=distance to next-nearest tree, n= sample size, and distribution is patchy if $A_1>0$, random if $A_1=0$, uniform if $A_1<0$ (Holgate 1965).

Since we used visual estimations of canopy cover in the vegetation subplots rather than spherical densiometer measurements, we verified the accuracy of the pre-treatment field estimates of canopy cover by comparing them with estimates derived from aerial images (digital orthophotos (DOQ)) of the fuels reduction project area. We used an overlay grid of 10m x10m cells (on the scale of the DOQ) to calculate canopy cover of each bird plot (# cells, to the nearest

quarter cell, covered with tree canopy/total # quarter cells in bird plot). Field visual estimates were 2% lower than the DOQ estimates (95% confidence interval -4.35% to 0.00325%, t_8=-2.3026, probability of obtaining a value as or more extreme due to chance alone (p)=0.0503).

We calculated avian species richness by summing the number of species detected on each plot over each year. We then determined the mean difference between years by treatment (mechanical-thinning or control) with matched pairs t-tests, performing a 2-sample t-test of difference by treatment.

In order to test our hypotheses, we selected bird species characterized as pinyon-juniper specialists or obligates (referred to collectively in this paper as pinyon-juniper specialists) and the most abundant species from each of four nesting guilds (tree nester, cavity nester, shrub nester, ground nester) for further analysis. Our occupancy analysis also included all species whose local distribution changed between years or after treatment. We chose to represent shrub-dependent birds as those species that nest in shrubs, since this study was conducted during the breeding seasons. Black-headed Grosbeaks are considered shrub nesters in our analysis, since Gambel oak is in a shrub-form at this study site, and all the trees are conifers. Many species had a single detection, so in order to reduce variance in our community data set and to enhance the detection of relationships between the community composition and environmental variables (McCune and Grace 2002), we did not include in our analysis bird species which comprised less than 1% of the total observations or that were observed only once in either year of surveying.

We did not have sufficient observations to determine detection functions for our selected species using distance sampling (Buckland et al. 2001). Therefore, we calculated mean relative abundance (MRA) for each bird species at each plot (total # detections/effort) for each year. Relative abundance assumes equal probability of detection. We determined the mean relative

abundance difference between years (2006 minus 2005) for each plot with matched pairs t-tests. We also performed a one-way analysis of difference by treatment (mechanical-thinning or control) with 2-sample t-tests for each bird species.

In order to identify variation in the probability of occupancy at any given plot due to the mechanical thinning, we used program PRESENCE (MacKenzie et al. 2006). Analysis of encounter histories with this program accounts for differences in probability of detecting a species in an occupied plot (p). Occupancy is here defined as the presence of at least one individual of the species on a plot. It is important to note that this detection probability differs from the probability of detecting an individual at a given distance from the observer, as is estimated in distance sampling. We created custom models with the following covariates: year, mechanical-thinning or control, and the interaction of year and treatment. We used Akaike information criterion (AIC) values for model selection. If the model with the lowest AIC rating (top model), or competing models (Δ AIC<2), included occupancy probability (Ψ) values dependent on the interaction covariate, and the otherwise identical model without the interaction covariate was not a competing model, we inferred an effect of thinning on occupancy for that species. For the remaining species which changed in local distribution of detections, we followed Mackenzie et al. (2006) in summing AIC weights from all models including an individual covariate to determine the most influential covariate(s) on Ψ and p.

RESULTS

Vegetation

Prior to thinning, control sites did not differ significantly from the mechanically-thinned units in tree stem density (0.25 more trees/ha, SE=t_{14}=1.47, p=0.1629), but averaged 7% higher pinyon-juniper canopy cover than the mechanical-thinning area (SE=3.3%, t_{14}=2.23, p=0.0420). Tree dispersion was greater in the mechanically-thinned unit prior to thinning (mean=3, SE=3.7) than in the control area (mean=1, SE=3.4). Tree maturity classes in the control units averaged 8% reproduction, 80% immature, 13% mature, and in treatment units prior to thinning 10% reproduction, 83% immature, and 7% mature.

Following mechanical thinning, the range of decrease in tree stem density on the plots was 49% to 100%, and canopy cover decreased by 57% to 100% (Table 1). On average, the distance from the count station to the closest pinyon increased by 62m, while the distance to the nearest juniper increased by 44m. After mechanical thinning, tree dispersion tended towards increased patchiness (index of aggregation increased from 3.2 to 9.3). We found a mean decrease of 18 stems/ha in sagebrush, rubber rabbitbrush decreased by 3 stems/ha, and Gambel oak increased by 2 stems/ha. Mean density of Utah serviceberry and sticky-leaved rabbitbrush did not change.

Breeding birds

Over two breeding seasons, we detected individuals of 48 species (Table 2), of which 63% were summer residents, 32 % year-round residents, and 5% (3 individuals) were classified as transient species. The most abundant species (311 detections) was the Spotted Towhee (*Pipilo maculates*), assuming equal detectability across all species. Other species with a relatively high number of detections included Brewer's Sparrow (*Spizella breweri*), Chipping Sparrow (*Spizella passerina*), Vesper Sparrow (*Pooecetes graminius).* and Blue-gray Gnatcatcher.

There was no difference in species richness between years in the mechanically-thinned units, relative to controls (t_{15}=0.11, p=0.9129). During the pre-treatment surveys, the number of species detected averaged 9.6 species per plot (SE=1.9) in the mechanically-thinned units, while species richness averaged 9.8 species per plot (SE=1.3) in the control units. In the second year of surveys, we detected a mean of 9.7 species per plot in the mechanically-thinned units (SE=1.5), and mean of 10 species per control plot (SE=1.8).

Although the number of bird species was not affected by thinning, avian community composition changed in both mechanically-thinned and control units (Table 3). The local distribution of detections of three tree nesters, two of which were pinyon-juniper specialists and a brood parasite changed following mechanical thinning. Two species detected on the mechanically-thinned plots during the pretreatment surveys were not detected on those plots after thinning, while three other species were detected in the treatment areas only after thinning. All Gray Vireo detections in the first survey season were on plots designated for mechanical thinning, yet all Gray Vireo detections in second year of surveys were found only in control areas. Black-throated Gray Warblers and Bushtits (*Psaltiparus minimus*) were detected on the treatment plots only after thinning, but were on control plots during both years. Brown-headed

Cowbirds (*Molothrus ater*), like Gray Vireos, were detected in the treatment areas only before thinning, and in the control areas only in the post-treatment surveys. Northern Mockingbirds (*Mimus polyglottos*) were detected only in the post-treatment surveys, but in both mechanically-thinned and control areas.

Of the14 species that we included in occupancy probability analysis, there was evidence of an influence of mechanical thinning on the site occupancy of Brown-headed Cowbirds and Gray Vireos (Table 4), after accounting for all non-treatment factors. For Black-headed Grosbeaks (*Pheucticus melanocephalus*), models including variation in site occupancy between years summed to 46% of the summed AIC weight, and models including variation in site occupancy between treatment assignment (thinning or control) summed to 46% of summed AIC weight. The differences between pre- and post-treatment site occupancy probability in Black-headed Grosbeaks are better explained by variation in occupancy probability between years, and between thinning and control units, than by the influence of the mechanical thinning (27% of summed AIC weight). Occupancy probability of the remainder of species that we analyzed was not influenced by mechanical thinning.

We examined the mean relative abundance of 11 species in 5 groups (Table 5). There was evidence of an effect of mechanical thinning on the mean relative abundance of 2 groups and 3 species (Table 6). Pinyon-juniper specialists collectively increased in control units and remained the same in treatment units. There was no effect of mechanical thinning on the abundance of Blue-gray Gnatcatchers, Black-throated Gray Warblers or Western Scrub-Jays. Gray Vireos, which increased in abundance in the control units, but decreased in the treated units, appeared to drive the group result.

The relative abundance of other tree nesters, taken as a group, increased in the control

units, but did not change in the mechanically-thinned units. We found evidence of an effect of mechanical thinning on the relative abundance of Chipping Sparrows, which increased in abundance in the control units and decreased in the treatment units. The thinning treatment did not change the abundance of Mourning Doves (*Zenaida macroura*). Because Gray Flycatchers (*Empidonax wrightii*) were detected only on the control plots, we were unable to assess for effects of thinning treatment on this species.

The mean relative abundance of the cavity nesting Ash-throated Flycatcher decreased in the control areas and increased in the mechanically-thinned areas. The shrub-nesting group decreased in abundance in the control units and increased in the mechanically-thinned units. Brewer's Sparrows appeared to drive this group result, with a decrease in abundance in control units and an increase in mechanically-thinned units. There was no treatment effect on the relative abundance of Black-Headed Grosbeaks. There was no effect of thinning on the relative abundance of the ground-nesting species, Spotted Towhees and Vesper Sparrows.

DISCUSSION

We designed our study to address predictions regarding avian response to the mechanical removal of pinyon pine and juniper trees on GSENM. First, we predicted that avian community composition would change as a result of the thinning treatment. It has been shown that avian communities respond to changes in vegetation structure, such as woodlands encroaching upon, or returning to, sagebrush- or grass-dominated vegetation communities (Knick et al. 2005; Medin et al. 2000; Rosenstock and van Riper 2001). It follows that changes in vegetation structure resulting from mechanical thinning at our study site might influence avian community

composition. The most extreme possible response of a species is exclusion from, or addition to, a treated area. At Ford Pasture, the local distribution of detections of five species changed in this manner during our study (Table 3). Three of these species (Black-throated Gray Warbler, Bushtit and Gray Vireo) nest in trees, while two of those (Black-throated Gray Warbler and Gray Vireo) are pinyon-juniper specialists. After accounting for differences in detection probability, the occupancy probability of Gray Vireos and Brown-headed Cowbirds was affected by mechanical thinning. Gray Vireos were present only in the plots designated for mechanical thinning in the pre-treatment surveys, but in the post-treatment surveys they were present uniquely in the control units. Brown-headed Cowbirds followed the same pattern of change in local distribution. We could find no influence of mechanical thinning on the occupancy probability of Black-throated Gray Warblers and Bushtits. No assessment can be made for a treatment effect on Northern Mockingbirds, since this species was not detected on any plots in the first season's surveys, but was detected on both control and thinned plots in the second survey year. As we predicted, community composition did change over the course of our study. After accounting for differences in detection probability, two of those changes appear to be due solely to the mechanical-thinning treatment.

Next, we made two predictions about the direction of response for two groups of species: pinyon-juniper specialists would be less abundant in mechanically-thinned units following treatment; and shrub-nesting species would remain unchanged or increase in abundance in mechanically-thinned units, since the thinning would remove trees but not shrubs. The changes in relative abundance that we found between survey years for these two groups support our predictions (Figure 2).

We found a treatment effect of mechanical thinning on the relative abundance of

pinyon-juniper specialists as a group. The relative abundance of pinyon-juniper specialists decreased in mechanically-thinned units and increased in control units after thinning. Gray Vireo was the only pinyon-juniper specialist for which occupancy was influenced by mechanical thinning, after accounting for differences in probability of detection.

The relative abundance of shrub nesters was affected by thinning, and as a group their relative abundance increased following mechanical thinning. This finding possibly reflects a reduction in competition with tree nesters for non-tree resources. Meanwhile, relative abundance of shrub nesters decreased between survey years in the control units. The occupancy probabilities of the species in this group were not influenced by thinning. Group relative abundance responded to mechanical thinning in the directions predicted.

Finally, we predicted that thinning would have a greater effect on pinyon-juniper specialists and shrub-nesting species than on other birds. Our analyses of group data did reveal an influence of thinning on the relative abundance of pinyon-juniper specialists and of shrub nesters, but no treatment effect on relative abundance in any of the other nesting guild groups (cavity, tree, ground). However, when each species is considered individually, there does not seem to be much difference between pinyon-juniper specialists or shrub-dependent species and other birds. The group response of pinyon-juniper specialists appeared to be driven by Gray Vireos, and the group response of shrub-nesters seemed to be driven by Brewer's Sparrows. Thinning influenced the relative abundance of one pinyon-juniper specialist, one shrub-nester, and one other tree-nesting species. After accounting for differences in detection probability, the occupancy probability of one pinyon-juniper specialist and one brood parasite were affected by mechanical thinning.

Impacts on Avian Species from Mechanical Thinning of Pinyon-Juniper

In our study, we found a significant effect of mechanical thinning on the mean relative abundance of Gray Vireos. All Gray Vireo detections in the first survey year were in plots designated for mechanical thinning, yet all Gray Vireo detections in second survey year were only in control plots. We suggest that following tree removal, the mechanically-thinned units no longer fulfilled the functions of breeding habitat for Gray Vireos, which nest and forage in trees. The Ford Pasture treatment was on a small scale, and control units contiguous to the mechanically-thinned units remained available to the vireos following treatment. At three sites on the Colorado Plateau, Schlossberg (2006) observed a similar pattern where Gray Vireos were absent in pinyon-juniper woodlands where trees had been killed by fire, but the vireos used neighboring pinyon-juniper woodlands which had not burned.

The control units in our study, even though chosen randomly, could have perhaps been of a lower quality breeding habitat than the mechanically-thinned units, and thus were not occupied until after the mechanically-thinned units had been altered. Schlossberg (2006) found Gray Vireo density to be positively correlated with proportion of junipers to pinyon pines, density of sagebrush (*Artemisia tridentata)*, and elevations between 1500 and 1900m. Sagebrush density did not vary between the pretreatment sites at Ford Pasture (t_{16}=0.27, p=0.887), and the study area is not on an elevational gradient. However, the proportion of junipers to pinyon pines was slightly lower (difference=0.1, SE=0.03) in the control areas than in the mechanically-thinned areas prior to thinning (t_{15}=-2.62, p=0.0189), and this may have accounted for the absence of Gray Vireos in the control units prior to the thinning treatment.

We found suggestive but inconclusive evidence of a mechanical-thinning effect on mean relative abundance of Chipping Sparrows, a tree-nesting bird which does not specialize in pinyon

pines or junipers. Chipping Sparrow detections increased in control units and decreased in treatment units after thinning, with occupancy probability significantly different between control and mechanical-thinned units. However, after accounting for differences in detection probability, the occupancy probability of this species was not affected by mechanical thinning. Chipping Sparrows are associated with pinyon-juniper woodland edges and other moderately open areas, and will use chained areas (Sedgwick 1987). Pavlacky and Anderson (2004) suggested a historical association of Chipping Sparrows with mature open woodlands produced by natural disturbance. Some of the thinned plots at Ford Pasture could have become lower quality breeding habitat for Chipping Sparrows because of increased distance between mature trees and the woodland edge.

The local distribution of Brown-headed Cowbirds changed over the course of our study, with occupancy probability affected by mechanical thinning. Cowbird abundance decreased in mechanically-thinned areas and increased in control areas after thinning. After accounting for differences in detection probability, occupancy probability of cowbirds was influenced by the treatment. Removal of trees and creation of 'edge' habitat through management activities have been implicated, along with cattle grazing, in the spread of Brown-headed Cowbird distribution throughout the United States (Lowther 1993). The first level of habitat selection in Brown-headed Cowbirds centers on wooded areas near the interface with fields or shrubs (Gates and Evans 1998). In our study, Cowbirds were in the areas of higher tree dispersion before the mechanical thinning. After thinning, they were found in the untreated areas bounding the mechanically-thinned units, the newly-created 'edge'. Female cowbirds require perches from which to surreptitiously observe other avian species in order to find nests to parasitize (Ehrlich et al. 1988). A positive correlation has been found between the number of tall perches available and

the frequency of cowbird parasitism of Black-throated Sparrows in central Arizona (Johnson and van Riper 2004). The removal of 49-100% of the trees in the mechanically-thinned units at Ford Pasture might have rendered treated areas less desirable to female cowbirds than the untreated units in which the tree canopy layer was not removed. Additionally, changes in the distribution of hosts might have influenced changes in the distribution of cowbirds. Blue-gray Gnatcatchers, Chipping Sparrows, Gray Vireos, and Spotted Towhees are frequent cowbird hosts, and Brown-headed Cowbirds may concentrate on one host species at the local level (Ehrlich et al. 1988; Ellison 1992).

No Observed Impacts on Avian Species from Mechanical Thinning of Pinyon-Juniper

The local distribution of Black-throated Gray Warbler detections changed following mechanical thinning. This species was detected only on the control plots in the pretreatment surveys, but in mechanically-thinned and control units after thinning. However, changes in relative abundance and occupancy in this species were not due to the thinning treatment. Black-throated Gray Warblers are associated with late successional pinyon-juniper woodlands (Pavlacky and Anderson 2001; Sedgwick 1987). At Ford Pasture, tree maturity was higher, on average, in the control units than the mechanically-thinned units prior to thinning. Pavlacky and Anderson (2004) suggest that the presence of species which prefer late successional woodlands in recently chained areas may be explained as an attraction to the openness of the treated area, brought about by an historical association with the low tree densities resulting from natural disturbances in mature woodlands. This may well be what we found in the Ford Pasture treatment.

The relative abundance and occupancy probability of Blue-gray gnatcatchers and of Western Scrub-Jays were not influenced by thinning. Blue-gray Gnatcatchers prefer woodland

edges and mature woodlands, as well as downed log and stump cover (Mannan 1980; Pavlacky and Anderson 2001). Sedgwick (1987) found this species in both shrubby chained areas (4-19 years after chaining) and mature woodlands. For gnatcatchers at Ford Pasture, the increase in downed trees and stumps might have balanced the loss of trees in the treated areas. Although Western Scrub-Jays have been categorized as pinyon-juniper obligates (Balda and Masters 1980), they do not build nests exclusively in these two tree genera. Vierling and Winternitz (2003) found that Western Scrub-Jays in Colorado preferred eastern redcedar (*Juniperus virginianus*) for nest sites (54%), with 21% of the nests in Gambel oak, and another 21% in pinyon pines. At Ford Pasture, it appears that Gambel oak, and possibly other shrubs, along with the few trees which remained in our plots provided enough nesting substrate, and that the small scale of the treatment left the surrounding untreated woodlands within acceptable proximity for Western Scrub-Jays.

Because Gray Flycatchers were detected only in the control units throughout the study, assessment for effects of mechanical thinning on this species is not possible. Pavlacky and Anderson (2001) found that Gray Flycatchers demonstrated a habitat preference for late-successional pinyon-juniper woodlands in Wyoming. The control units at Ford Pasture contained trees of greater maturity, on average, than the mechanically-thinned units prior to thinning.

The mechanical thinning did not influence the relative abundance or the occupancy probability of Mourning Doves, another tree-nesting species that does not rely on pinyon pines and junipers. Mourning Doves have been classified as habitat generalists (Stauffer and Best 1980), and might be less sensitive than other species to changes in vegetation structure. The relative abundance and occupancy of Black-headed Grosbeaks, which nest in broadleaved trees

or shrubs, was not affected by removing pinyon-pines and junipers. There are no broadleaved trees at Ford Pasture, but Gambel oak and other shrubs are available and were not cut.

Thinning did not affect the abundance or occupancy of Spotted Towhees and Vesper Sparrows. Both are ground nesters of shrubby or grassland steppes, commonly found in early successional stages of pinyon-juniper woodlands. Although the stumps and fallen trunks of cut trees might make some places unavailable for nesting, we found that the shrub and open ground (grass, forb, litter, bare soil) components of vegetation structure were virtually unchanged by the mechanical thinning.

The thinning treatment also had no effect on Ash-throated flycatchers, which rely on snags for cavities in which to nest (Scott et al. 1977). Snags were not cut in the treatment at Ford Pasture, nor were snags created by the cutting treatment. The number of snags did not change in the study area over the course of the study and this resulted in a stable Ash-throated flycatcher population.

Other Impacts on Avian Species from Mechanical Thinning of Pinyon-Juniper

We found suggestive evidence of a mechanical-thinning effect on increasing mean relative abundance of Brewer's Sparrows, although occupancy probability was not significantly affected by thinning. Brewer's Sparrows prefer open habitat with large shrubs and low shrub diversity within immature pinyon-juniper woodlands (Pavlacky and Anderson 2004; Sedgwick 1987) and

in other vegetation communities (Rotenberry and Wiens 1980; Wiens 1985). Prior to thinning, we detected fewer Brewer's Sparrows in the treatment units, which had a lower index of tree dispersion and lower tree maturity, than in the more mature woodlands of the control units where tree distribution was more aggregated. Relative abundance of Brewer's Sparrows increased in the thinned units after treatment, while decreasing in the control units. The mechanical thinning appears to have increased breeding habitat quality, so that post-treatment the area supported a larger number of nesting Brewer's Sparrows.

Bushtits were detected in the mechanically-thinned areas only after treatment, but in the control areas during both years. Occupancy probability differed between mechanically-thinned and control areas, but was not influenced by the mechanical-thinning treatment. We observed the same pattern in Black-throated Gray Warblers, and we suggest that this might be due to habitat selection based on an attraction to open areas which operates at both ends of the successional spectrum (woodlands opened by fuels reduction management actions, and mature woodlands opened by natural disturbance).

From a sagebrush restoration manager's perspective, the changes in local distribution of Brown-headed Cowbirds at Ford Pasture might be viewed as a positive, rather than negative, effect of the mechanical-thinning treatment. The disappearance of this brood parasite from the treated units might be beneficial to shrub-nesters such as Brewer's Sparrows and other avian species which remain or increase in abundance after pinyon-juniper thinning. However, the presence of this species in the control units after the treatment could exacerbate the stress on Gray Vireos and Chipping Sparrows, both of which were effected by the treatment, and both of which are frequent cowbird hosts.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

On the Colorado Plateau, as pinyon and juniper trees establish in shrublands and grasslands, land managers are faced with the need to achieve a delicate balance between habitat restoration of shrub steppe, while avoiding negative impacts on woodland-dependent bird species.

Overall, we found few changes in community composition following mechanical removal of trees during our study. An important limitation that we recognize is that our surveys were conducted during only two breeding seasons, one prior to and one following mechanical thinning. We believe that more profound changes in community composition or abundance might be revealed if avian surveys were to continue. For example, Wiens (1985) found a time lag of several years in the response of Brewer's Sparrows and other bird species to habitat changes caused by herbicide application to shrub steppe. Because the thinning in our study was performed in April, breeding habitat selection was probably affected only on a very local scale for early migrants. Additionally, the response that we observed might have been a short-term reaction to disturbance during the cutting activity, rather than a long-term response to the resulting changes in habitat structure.

In our study, pinyon-juniper specialists as a group showed a decline in abundance within mechanically-thinned areas. Removing live trees from pinyon-juniper woodlands decreases breeding habitat for Gray Vireos. In response to thinning, Gray Vireos were eliminated from the treated units, and began using contiguous untreated pinyon-juniper woodland (control units). Similar mechanical-thinning projects on a larger scale could have serious implications for this bird, as suitable breeding habitat is presently limiting and the species is uncommon within GSENM. The Gray Vireo has been identified as a Species of Conservation Concern on the Colorado Plateau and at the national level (United States Fish and Wildlife Service [USFWS]

2002). Although there was a pattern in detections which suggested Black-throated Gray Warblers began using the mechanically-thinned areas after thinning, relative abundance and site occupancy proportions of this species were not significantly influenced by thinning. The treatment also did not affect the relative abundance or occupancy probabilities of the other pinyon-juniper specialists at Ford Pasture. Some species characterized as pinyon-juniper specialists were absent during the entire study, and are probably not normal residents of the study area.

As a group, shrub nesters increased in relative abundance in the mechanically-thinned areas and decreased in the control areas, due to the mechanical-thinning treatment. Detections of Brewer's Sparrow, a Species of Concern in the Mountain-Prairie region (USFWS 2002), increased in the treated areas, but occupancy was not affected by thinning. This provides some evidence that mechanical thinning might produce positive changes over time for avian sagebrush species.

If the changes that we observed in our study continue in the future in the same direction, shrub nesting species might positively benefit from hand-cutting treatments. Ground nesting bird species should also benefit from the early successional woodlands that will arise in the mechanically-thinned units. Although it is beyond the scope of our study to compare hand cutting to other fuels reduction methods, it seems likely that prescribed fire and chaining might be more destructive to shrubs. We thus see hand cutting of pinyon pines and junipers for sagebrush restoration projects, in areas like Ford Pasture, as a viable alternative to prescribed fire and chaining.

Tree removal in pinyon-juniper woodlands on a small scale may meet sagebrush restoration objectives only temporarily because of strong mutualistic relationships between tree

species and seed dispersing birds (Balda 1987). However, repeated small scale projects require a lower financial commitment in a single year and are more likely to fit legal compliance requirements than a large scale project. This approach may be useful where management goals are to minimize detrimental effects of sagebrush restoration on Gray Vireos and other pinyon-juniper specialists.

Managers should recognize that multiple, small-scale pinyon-juniper reduction projects will produce more "edge" than a single large-scale mechanically-thinned treatment, fragmenting the woodlands into a number of artificially defined units. This could result in an increase in nest parasitism by Brown-headed Cowbirds. In our study, Brown-headed Cowbirds increased in the control areas adjoining the mechanically-thinned sites. If minimizing negative impact to woodland species is an objective, it is important to consider the possible implications of increasing the chance of Brown-headed Cowbird nest parasitism. Goguen and Mathews (2000) found that Brown-headed Cowbird abundance declined as distance from grazing increased in pinyon-juniper woodlands. Short-term cattle exclusion from the treatment area and nearby allotments, following mechanical thinning, might temporarily offset the expected increase in Brown-headed Cowbird abundance that results from food resources provided by the cattle coupled with fragmentation of the woodland.

Pinyon pines and junipers are both slow-growing trees (Samuels and Betancourt 1982), some exceeding 100 years of age before reaching their mature size (Bradshaw and Reveal 1943). Because avian community composition varies along the successional gradient of pinyon-juniper woodlands (Pavlacky and Anderson 2001; Rosenstock and van Riper 2001), a series of small-scale mechanical-thinning projects performed over time could effectively rotate treatment units through successional stages, maximizing the number of species for which habitat is

provided.

Further studies addressing long-term effects in abundance, occupancy, and nesting success, should be conducted to ensure that the adaptive management policies of land management agencies are based on an understanding of the true implications of thinning pinyon-juniper woodlands. In the interim, limiting the scale of fuels reduction projects in pinyon-juniper vegetation communities may maximize the benefits of management to both the pinyon-juniper and sagebrush steppe avian communities.

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Table 1. Effects of mechanical-thinning treatment on tree (*Pinus edulis* and *Juniperus osteosperma* combined) and shrub characteristics from 9 bird plots on Ford Pasture, Grand Staircase Escalante National Monument.

Bird Plot	% Tree stems removed	% Canopy Cover Removed	Tree dispersion pre-treatment	Tree dispersion post-treatment	Mean change no. shrub stems (2006-2005)	Mean change no. shrub species (2006-2005)
HC00	100	100	25.51	18.86	9	1
HC03	49	57	-0.31	-0.31	-14	0
HC06	86	81	-0.22	-0.45	-1	0
HC09	100	100	0.49	0.75	-3	0
HC12	a	a	0.60	0.45	-1	0
HC22	100	100	0.19	-0.25	0	0
HC23	100	100	2.50	55.19	-4	0
HC25	100	100	0.27	4.05	-18	0
HC26	100	100	0.08	5.65	-3	0

a = no trees on plot prior to mechanical thinning

Table 2. Avian species, USGS alpha code, and number detected on 20 plots in Ford Pasture Fuels Reduction project area, May-June 2005 and May-June 2006.

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Common Name	Scientific Name	Code	No. on plots
Ash-throated Flycatcher	*Myiarchus cinerascens*	ATFL	63
Black-chinned Hummingbird	*Archilochus alexandri*	BCHU	4
Black-crowned Sparrow	*Spizella atrogularis*	BCSP	1
Black-headed Grosbeak	*Pheucticus melanocephalus*	BHGR	45
Black-throated Gray Warbl	*Dendroica nigrescens*	BTYW	26
Black-throated Sparrow	*Amphispiza bilineata*	BTSP	8
Blue-gray Gnatcatcher	*Polioptila caerulea*	BGGN	105
Brewer's Sparrow	*Spizella breweri*	BRSP	160
Brown-headed Cowbird	*Molothrus ater*	BHCO	7
Bushtit	*Psaltriparus minimus*	BUSH	36
Cassin's Kingbird	*Tyrannus vociferans*	CAKI	2
Chipping Sparrow	*Spizella passerina*	CHSP	119
Common Nighthawk	*Cordeiles minor*	CONI	2
Common Poorwill	*Phalaenoptilus nuttallii*	COPO	
Common Raven	*Corvus corax*	CORA	
Dark-eyed Junco	*Junco hyemalis*	DEJU	2
Gray Flycatcher	*Empidonax wrightii*	GRFL	7
Gray Vireo	*Vireo vicinior*	GRVI	11
Green-tailed Towhee	*Pipilo chlorurus*	GTTO	1
Hairy Woodpecker	*Picoides villosus*	HAWO	1
House Finch	*Carpodacus mexicanus*	HOFI	9
Lark Sparrow	*Chondestes grammacus*	LASP	22
Lazuli Bunting	*Passerina amoena*	LAZB	2
Long-billed Curlew	*Numenius americanus*	LBCU	1
Lincoln's Sparrow	*Melospiza lincolnii*	LISP	2
Mountain Bluebird	*Sialia currucoides*	MOBL	14
Mountain Chickadee	*Poecile gambeli*	MOCH	1
Mourning Dove	*Zenaida macroura*	MODO	37
Northern Flicker	*Colaptes auratus*	NOFL	4
Northern Harrier	*Circus cyaneus*	NOHA	1

Table 2 (cont'd). Avian species, USGS alpha code, and number detected on 20 plots in Ford Pasture Fuels Reduction project area, May-June 2005 and May-June 2006.

Common Name	Scientific Name	Code	No. on plots
Northern Mockingbird	*Mimus polyglottos*	NOMO	7
Pinyon Jay	*Gymnorhinus cyanocephalus*	PIJA	
Red-tailed Hawk	*Buteo jamaicensis*	RTHA	3
Sage Sparrow	*Amphispiza belli*	SAGS	3
Say's Phoebe	*Sayornis saya*	SAPH	5
Spotted Towhee	*Pipilo maculatus*	SPTO	311
Townsend's Solitaire	*Myadestes townsendi*	TOSO	5
Turkey Vulture	*Cathartes aura*	TUVU	
Vesper Sparrow	*Pooecetes graminius*	VESP	101
Violet-green Swallow	*Tachycineta thalassina*	VGSW	2
Virginia's Warbler	*Vermivora virginiae*	VIWA	4
Western Bluebird	*Sialia mexicana*	WEBL	59
Western Meadowlark	*Sturnella neglecta*	WEME	29
Western Tanager	*Piranga ludoviciana*	WETA	3
Wild Turkey	*Melagris gallopavo*	WITU	
Western Scrub-Jay	*Aphelocoma californica*	WSJA	16
Yellow-rumped Warbler	*Dendroica coronata*	YRWA	4

Table 3. Patterns of detected presence (+) and absence (-) of detection for avian species in control and mechanically-thinned areas before (2005) and after (2006) thinning of pinyon-juniper woodlands. The patterns shown for Brown-headed Cowbird (BHCO) and Gray Vireo (GRVI) reflect the influence of thinning on occupancy after accounting for variation in detection probability.

		Control		Treatment	
Species*	Nesting guild	2005	2006	2005	2006
BTYW	Tree/PJ	+	+	-	+
GRVI	Tree/PJ	-	-	+	-
BHCO	Parasite	-	+	+	-
BUSH	Tree	+	-	-	+
NOMO	Tree	-	+	-	+

*See Table 2 for species codes and names

Table 4. Summed AIC weights of occupancy probability (Ψ) and detection probability (p) covariates for avian species. Weights were not summed for Gray Vireo and Brown-headed Cowbird, for which effect of mechanical thinning on occupancy, denoted by the interaction covariate (trtyrint), was an element of the model with the lowest and second-lowest AIC values, respectively. trt = treatment assignment (treat or control), yr = year.

Species*	Occupancy Covariate			Detectability Covariate		
	? (trtyrint)	? (trt)	? (yr)	p(trtyrint)	p(trt)	p(yr)
BGGN	N/A	26%	N/A	N/A	71%	18%
BTYW	N/A	N/A	N/A	23%	82%	76%
GRVI	**top model**	N/A	N/A	N/A	N/A	N/A
WSJA	N/A	36%	30%	15%	33%	36%
BHGR	27%	46%	46%	58%	77%	76%
BRSP	N/A	N/A	N/A	59%	N/A	N/A
CHSP	N/A	25%	N/A	27%	96%	46%
MODO	N/A	N/A	N/A	19%	43%	80%
ATFL	N/A	25%	N/A	20%	75%	41%
SPTO	N/A	N/A	N/A	42%	59%	75%
VESP	N/A	N/A	N/A	32%	100%	98%
BHCO	**competing model**	N/A	N/A	N/A	N/A	N/A
BUSH	N/A	33%	N/A	N/A	42%	23%
NOMO	N/A	18%	48%	N/A	17%	47%

*See Table 2 for species codes and names

Table 5. Mean relative abundance (y) and standard errors of birds, by group (pinyon-juniper specialist (PJ) or nesting guild) and by species, on 11 control and 9 mechanically-thinned plots before (2005) and after (2006) treatment.

Guild	Species*	Control				T	
		2005		2006		2005	
		y	SE	y	SE	y	SE
PJ	Group	0.2	0.06	0.3	0.06	0.1	0.04
PJ	BGGN	0.7	0.48	0.7	0.14	0.3	0.09
PJ	BTYW	0.2	0.06	0.3	0.09	0.0	0.00
PJ	GRVI	0.0	0.00	0.1	0.04	0.1	0.48
PJ	WSJA	0.0	0.00	0.2	0.13	0.1	0.08
Shrub	Group	0.9	0.16	0.9	0.21	1.1	0.13
Shrub	BHGR	0.1	0.04	0.3	0.09	0.1	0.07
Shrub	BRSP	0.5	0.11	0.0	0.04	1.3	0.16
Tree	Group	0.4	0.52	0.6	0.46	0.3	0.09
Tree	CHSP	0.6	0.20	0.9	0.12	0.6	0.12
Tree	MODO	0.1	0.04	0.3	0.08	0.0	0.03
Cavity	ATFL	0.5	0.11	0.3	0.07	0.2	0.08
Ground	Group	0.7	0.12	0.6	0.16	0.8	0.13
Ground	SPTO	1.5	0.18	1.7	0.21	1.2	0.17
Ground	VESP	0.4	0.13	0.1	0.11	1.0	0.21

*See Table 2 for species codes and names

Table 6. Mean difference in mean relative abundance (2006 minus 2005) and standard errors from matched-pairs t-tests, and estimates of mechanical-thinning effect on mean relative abundance with outcomes of two-sample t-tests on the mean difference in relative abundance (2006-2005) on control plots (Δ control) vs. the mean difference in relative abundance (2006 minus 2005) on treatment plots (Δtreatment) for PJ specialists and other common species, by group (pinyon-juniper specialist (PJ) or nesting guild) and by species.

Guild	Species*	Difference (2006-2005)				Effect of Mechanica		
		Control		Treatment		(? Control) - (? Tr		
		y	SE	y	SE	y	SE	df
PJ	Group	0.1	0.06	-0.01	0.03	0.1	0.07	71
PJ	BGGN	0.0	0.16	0.1	0.11	-0.1	0.19	17
PJ	BTYW	0.1	0.10	0.0	0.02	0.1	0.10	11
PJ	GRVI	0.1	0.05	-0.1	0.05	0.2	0.07	18
PJ	WSJA	0.2	0.13	-0.1	0.08	0.2	0.15	17
Shrub	Group	-0.1	0.10	0.3	0.16	-0.4	0.19	28
Shrub	BHGR	0.2	0.91	0.2	0.06	0.0	0.11	17
Shrub	BRSP	-0.4	0.12	0.3	0.33	0.7	0.36	10
Tree	Group	0.2	0.11	-0.1	0.11	0.2	0.16	37
Tree	CHSP	0.2	0.20	-0.3	0.17	0.5	0.27	18
Tree	MODO	0.1	0.09	0.2	0.09	-0.1	0.13	18
Cavity	ATFL	-0.1	0.09	0.1	0.11	-0.2	0.14	16
Ground	Group	-0.1	0.10	0.6	0.10	-0.2	0.14	55
Ground	SPTO	0.3	0.19	0.7	0.07	-0.4	0.21	13
Ground	VESP	-0.3	0.12	-0.4	0.13	0.1	0.18	18

*See Table 2 for species codes and name y=mean response SE=standard error
df=degrees freedom p=probabilityFig.1. Ford Pasture Fuels Reduction project area at Grand Staircase Escalante National Monument in southern Utah.

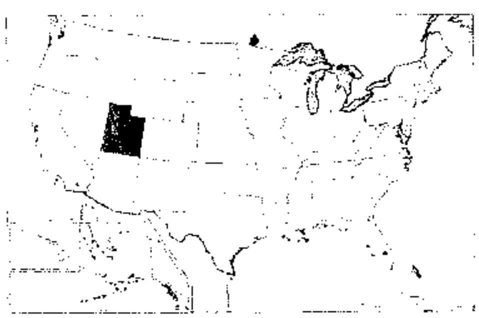
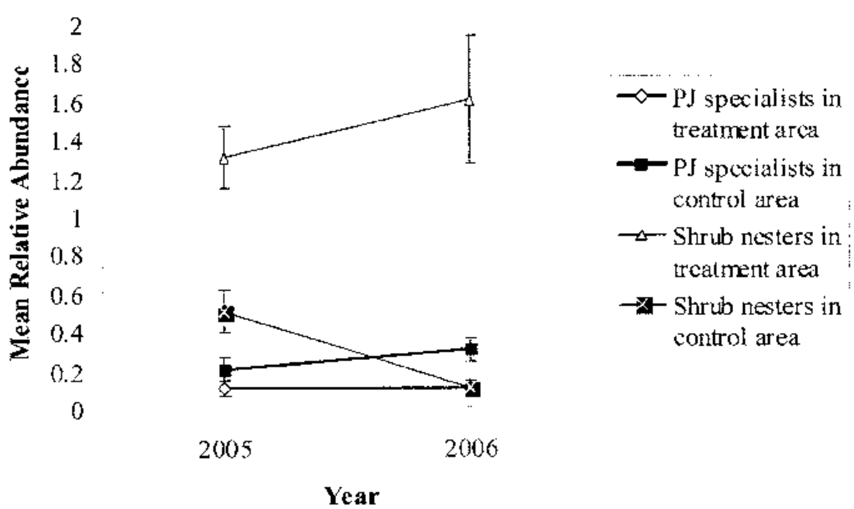
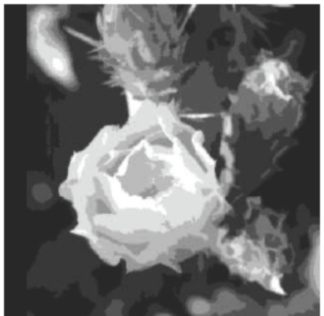


Fig.2. Changes in mean relative abundance of avian species specializing in pinyon-juniper habitat (PJ specialists) and shrub-nesting birds due to mechanical removal of pinyon pine and juniper trees between the 2005 and 2006 breeding seasons, and changes in mean relative abundance of the same groups not subjected to mechanical thinning (control area). Bars represent the Standard Error for each value.



Additional Materials



Epilogue

Thank you everyone attending and participating in this, our 3rd decade celebration of science & research. The Science Symposium Aug. 2, 3, 4 in Kanab and Escalante, and this summary, are a celebration of dedicated people who care about this intriguing place we call Grand Staircase-Escalante National Monument.

Our Monument Management Plan states: The primary purpose for establishing GSENM is to protect the scientific and historic resources described in the Proclamation. It provides further direction:

Information gathered through the research program will be used to improve mgmt. practices and protect resources. For example, baseline inventories can identify sensitive areas that may be affected by proposed activities, allowing BLM to take appropriate measures for the protection of such resources.

Two basic precepts of the Monument's vision are:

1) First and foremost…safeguarding the remote and undeveloped frontier character of the Monument is essential to the protection of the scientific and historic resources as required by the Proclamation; and

2) …the Monument provides an unparalleled opportunity for the study of scientific and historic resources.

Our plan directs us to set priorities and budgets to focus on understanding the resources of the Monument while assisting in the development of improved and innovative land management restoration and rehabilitation practices. The first priority for BLM-sponsored research is to study, collect, or record scientific information most at risk of being damaged or lost through disturbance or the passage of time. Second priority is to gather baseline data on all resources, and third, to conduct applied research regarding the management of natural systems, including disturbance and recovery strategies.

The model originally established here, once the monument was designated in 1996, was to have scientists on staff, who would collaborate with university and NGO counterparts to actively engage in science and research relevant to this special place. Although the federal budget drives a different model now, staff and researchers still seek collaborative projects - both basic and applied.

As scientists poke and prod like a doctor examining her patient, what will we do with what we learn? Are we sharing our knowledge, are we mentoring youth to take on the job of stewardship and deep inquiry? Are we making the hard environmental choices today that set a solid foundation for future generations?

In a recent issue of NatGeo, writer David Quammen reflects that 140 years ago in the greater Yellowstone ecosystem, people were negotiating a peace treaty with the wild. That negotiation continues today with urgency all over the planet as the human world expands and the natural world retreats. Can we come to terms?

I hope so.

I can tell you that this place is truly worth the effort.

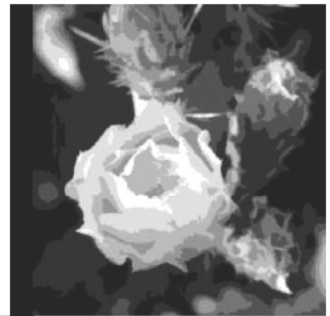
Carolyn Z. Shelton
Assistant Monument Manager
Science & Visitor Services

Cultural & Earth Sciences Forum – Kanab, UT Day 1 (August 2)				
Crescent Moon Theater, 150 S 100 E, Kanab, UT 84741				
Time Slot	**Topic**	**BLM Facilitator**	**Presenter**	**Subject**
8 am - 8:10	Introduction	Cindy Staszak	Cindy Staszak	Welcome, Housekeeping, Speaker Introductions
8:10-8:30	Keynote Speech		Carolyn Shelton	Learning from the Land GSENM Science 2006-2016
8:30 – 8:40	Paleontology Introduction	Dr. Alan Titus	Dr. Alan Titus	Introduction of BLM Regional Paleontologist Dr. Greg McDonald & Overview of GSENM Paleontology Program
8:40-10:25	Paleontology	Dr. Alan Titus	Dr. Barry Albright,	15 Yrs of Paleontology in GSENM: Old Discoveries, New Discoveries & What We've Learned
			Dr.Joshua Lively	Fossil Turtles of the Kaiparowits Formation
			Dr. Joe Sertich	Denver Musem of Natural Science's (DMNS) Laramidia Project: New Discoveries from the Dinosaur Ecosystems of GSENM
10:35-10:50				15 minute break
10:55-12:30	Geology	Dr. Alan Titus	Dr. Alan Titus	Overview of GSENM Geology
			Dr. David Loope	Microbes pumping iron at the GSENM
			David Wheatley	Clastic Pipes & soft sediment deformation of the Carmel Formation
			Dr. Fred Zelt	Mass Extinction, Climate Changes & Huge Volcanic Eruptions: What the Cretaceous Tropic Shale Tells Us About When Seawater Flooded GSENM
12:35–1:15 pm				LUNCH PROVIDED
1:20-3:00	Archaeology	Matt Zweifel	Jerry Spangler	Archaeological perspective on GSENM
			Matt Zweifel	Past 10 Years of Archaeology on GSENM
			Rob D'Andrea	Paleoecology of GSENM: Human Landscape Impacts & Management Implications on the Colorado Plateau
			Brian Storm	The Forgotten World of the Archaic
			David Sabata	Ethnobotany at Old Corral
			Dr. Pavlik/ Dr.Louderback	Archaeology & Conservation of the Four Corners Potato
3:05-3:20				15 minute break
3:25-4:25	Human History	Matt Zweifel	Paula Mitchell,	GSENM Digital Research Library at Southern Utah University
			Marsha Holland	Oral Histories (Residents & Designation)
4:30-5:00	Wrap-up	Carolyn Shelton		Final Questions & Answer Session & Thank You's
7:00 -8:30 p	Evening Presentation at GSENM Kanab Visitor Center, 745 E Hwy 89, Kanab, UT		Dr. Joseph Sertich DMNS	A Tale of Two Reptiles: The Lost Landmass of Laramidia & the Origins of the Modern World

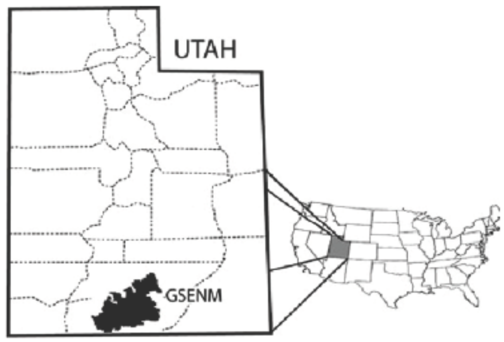
Field Trips Day 2 (August 3) Weather Permitting						
Advance registration at http://gsenm.org/home/2016-science-forum/ with registration for remaining spaces on Day 1 of Science Symposium in Kanab.						
Topic	**Trip Leader**	**Vehicle Required**	**Staging Area**	**Time**	**Group Limit**	**Provided**
Paleontology - Understanding the Significance of Rainbows & Unicorns	Dr. Alan Titus	4 Wheel Drive (WD) Hi Clearance (HC)	GSENM Cannonville Visitor Center, 10 Center Street Cannonville, UT	10:00 am - 2:30 pm	25	Lunch
Geology - Take a Peek at Slot Canyons: Spooky, Peekaboo & Brimstone	Dr. David Loope	All-Wheel-Drive (AWD) HC recom.; 4WD is best	Escalante Interagency Visitor Center 755 West Main Escalante, UT	9:00- am - 2:30 pm	12	Lunch
Microbiology - Microbial Wildlife: Nature's Smallest, Unpaid Engineers	Dr. Harry Kurtz	AWD Hi Clearance recom.; 4WD is best	Escalante Interagency Visitor Center 755 West Main Escalante, UT	8:30 am - 12:00 pm	12	Snacks
Soils - From Jurassic Park to the Grand Staircase: Biological Crusts, in the Past, Present & Future	Dr. Mary O'Brien and Dr. Ellen Bishop	4WD Hi Clearance	GSENM Cannonville Visitor Center, 10 Center Street Cannonville, UT	9:00 am - 4:00 pm	25	Lunch
Geology - The Cretaceous Tropic Shale Formation: Witness to Mass Extinction	Dr. Fred Zelt	4WD Hi Clearance	GSENM Big Water Visitor Center 100 Revolution Way, Big Water, UT	8:30 am - 6:00 pm	12	Lunch
Botany - Escalante River Restoration	Dr. Mike Scott, & Melissa Masbruch	2WD	Escalante Interagency Visitor Center 755 West Main Escalante, UT	8:30 am - 12:30 pm	25	Lunch
Archaeology - Paleoecology, Ethnobotany & Life as the Anasazi Knew It	Matt Zweifel	4WD Hi Clearance	GSENM Kanab Headquaters Building 669 South Highway 89, Kanab, UT	8:00 am - 4:00 pm	12	Lunch
Biology - 650 Species of Gentle, Native Bees: GSENM is Beeyond Beelief	Dr. Michael Orr	2-Wheel Drive	GSENM Big Water Visitor Center 100 Revolution Way, Big Water, UT	9:30 - 11:30 am	20	Snacks
Evening Presentation - Take a Peek at Slot Canyons: Spooky, Peekaboo and Brimstone	Dr. David Loope	N/A	Escalante Interagency Visitor Center 755 West Main Escalante, UT	7:00 - 8:30 pm	N/A	N/A
Evening Presentation - The Darkest Skies of Them All: Grand Staircase-Escalante National Monument is the Universe's Showcase	Shannon Holt, Asis Carlos, & Craig Tanner	2-Wheel Drive	Escalante Interagency Visitor Center 755 West Main Escalante, UT	9:00 - 11:00 pm	N/A	N/A

Biological & Social Sciences Forum – Escalante, UT Day 3 (August 4)				
Escalante Interagency Visitor Center, 755 W Main Escalante, UT (EIC)				
Time Slot	**Topic**	**BLM Facilitator**	**Presenter**	**Subject**
7:00-8:00 am	Citizen Science	Terry Tolbert	Terry Tolbert	Hands-on: Hummingbird Research
8:00-8:10	Introduction	Cindy Staszak	Cindy Staszak	Welcome, Housekeeping, Speaker Introductions
8:10-9:55	Recreation/ Social Science	Allysia Angus	Allysia Angus	Visitor Use Perspective
			Dr. Britt Mace. Southern Utah University	Soundscapes of Grand Staircase-Escalante National Monument
			Dr. Tim Casey, Mesa State University	A Monumental Sense of Place: Connections to GSENM
10:00-10:15				15 minute break
10:20-11:55	Botany	Doug Reagan	Amber Hughes	GSENM Botany Perspective
			Raymond Brinkerhoff	Old Corral Restoration Project
			Adrienne Pilmanis	Seeds of Success
			Dr. Mike Scott	Role of Russian-olive Removal in Longterm Channel Changes Along the Escalante River
12:00–12:45 pm				LUNCH PROVIDED
12:45-2:30	Wildlife/Biology	Kevin Miller	Cameron McQuivey	GSENM Wildlife/Biology Perspective
			Cameron McQuivey	Bighorn, Mt. Lion, & Pronghorn Studies
			Terry Tolbert	Hummingbird & Bat Studies
			Dr. Michael Orr, USDA-ARS Bee Lab	Between a Rock & a Hard Place To Live – A New Bee Nesting in Sandstone
			Dr. Paul Opler	Survey of Lepidoptera in Grand Staircase-Escalante: Status & Opportunities
			Dr. Harry Kurtz	Microbial Communities of the Jurassic Navajo Sandstone & Their Role in Shaping the Landscape
2:35- 2:50				15 minute break
2:55-4:25	Soils & Hydrology	Ken Bradshaw	Kevin Miller	GSENM Ecological Perspectives
			Amy Dickey, Utah Division of Water Quality	Water Quality
			Dr. Mary O'Brien & Dr. Ellen Bishop	Early & the Late: 2014-2015 Biocrust Study in GSENM
			Dr. Mike Duniway	New Concepts & Tools for Managing Colorado Plateau Landscapes: Soils, Ecological Potential & Ecological Dynamics
4:30-5:00	Wrap-up	Carolyn Shelton		Final Questions & Answer Session & Thank You's
7:00 -8:30 pm	Recreation Focus Group at EIC	Allysia Angus	Dr. Tim Casey	Monumental Sense of Place: Grand Staircase Region Recreation Experience Baseline Study Focus Group
7:00 -8:30 pm	Evening Presentation at EIC	Kevin Miller	Dr. Mikel Stevens	Are There Really More Than 70 Species of Penstemon Flowers in Utah?

Visitor Information



Visitor center exhibits share research and scientific discoveries with visitors and students. Visitor Centers have dramatic murals and a topographic relief model of the Monument and surrounding area photographed from the Land-sat 7 Satellite, 438 miles above earth.



Location map of Grand Staircase-Escalante National Monument within Utah.

GSENM Headquarters
Bureau of Land Management
669 East Hwy 89A
Kanab, UT 84741
(435) 644-1200
Administration and Paleontology

Big Water Visitor Center
20 Revolution Way
Big Water, UT 84741
(435) 675-3200
Theme: Paleontology and Geology

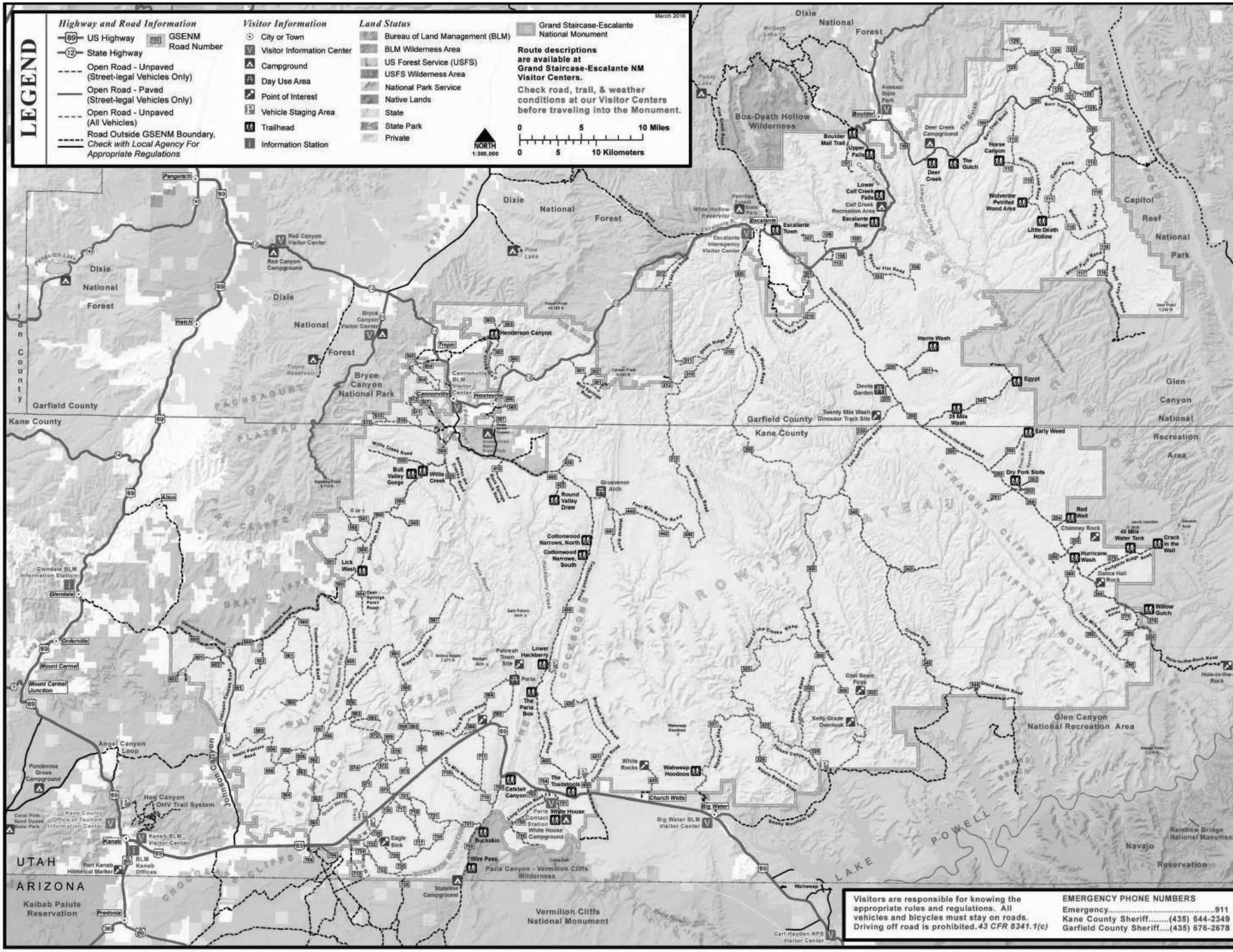
Boulder Contact Station
@ Anasazi State Park Museum
460 UT-12
Boulder, UT 84716
(435) 335-7382
Theme: Archaeology

Cannonville Visitor Center
10 Center Street
Cannonville, UT 84718
(435) 826-5640
Theme: Paiutes and Pioneers

Escalante Interagency
Visitor Center
755 West Main
Escalante, UT 84726
(435) 826-5499
Theme: Flora, Fauna, and Soils

Kanab Visitor Center
745 East Hwy 89
Kanab, UT 84741
(435) 644-1300
Theme: Archaeology and Geology

Glendale Information Station
155 North Main Street
Glendale, UT 84729
Restrooms and picnic area


LEGEND
March 2016
Highway and Road Information
89 US Highway
12 State Highway
GSENM Road Number
Open Road - Unpaved (Street-legal Vehicles Only)
Open Road - Paved (Street-legal Vehicles Only)
Open Road - Unpaved (All Vehicles)
Road Outside GSENM Boundary, Check with Local Agency For Appropriate Regulations
Visitor Information
City or Town
Visitor Information Center
Campground
Day Use Area
Point of Interest
Vehicle Staging Area
Trailhead
Information Station
Land Status
Bureau of Land Management (BLM)
BLM Wilderness Area
US Forest Service (USFS)
USFS Wilderness Area
National Park Service
Native Lands
State
State Park
Private
Grand Staircase-Escalante National Monument
Route descriptions are available at Grand Staircase-Escalante NM Visitor Centers.
Check road, trail, & weather conditions at our Visitor Centers before traveling into the Monument.
NORTH
1:300,000
0 5 10 Miles
0 5 10 Kilometers
Dixie National Forest
Box-Death Hollow Wilderness
Boulder
Escalante
Capitol Reef National Park
Garfield County
Kane County
Bryce Canyon National Park
Glen Canyon National Recreation Area
Kaiparowits Plateau
Panguitch
Tropic
Cannonville
Henrieville
Glendale
Orderville
Mount Carmel
Mount Carmel Junction
Kanab
Big Water
Church Wells
UTAH
ARIZONA
Kaibab Paiute Reservation
Fredonia
Vermilion Cliffs National Monument
Paria Canyon - Vermilion Cliffs Wilderness
Lake Powell
Navajo Reservation
Rainbow Bridge National Monument
Carl Hayden NPS Visitor Center
Hole-in-the-Rock
Visitors are responsible for knowing the appropriate rules and regulations. All vehicles and bicycles must stay on roads. Driving off road is prohibited. 43 CFR 8341.1(c)
EMERGENCY PHONE NUMBERS
Emergency.........911
Kane County Sheriff........(435) 644-2349
Garfield County Sheriff....(435) 676-2678

Establishment of Grand Staircase-Escalante National Monument, September 18, 1996

By William J. Clinton, President of the United States of America

A Proclamation

The Grand Staircase-Escalante National Monument's vast and austere landscape embraces a spectacular array of scientific and historic resources. This high, rugged, and remote region, where bold plateaus and multi-hued cliffs run for distances that defy human perspective, was the last place in the continental United States to be mapped. Even today, this unspoiled natural area remains a frontier, a quality that greatly enhances the monument's value for scientific study. The monument has a long and dignified human history: it is a place where one can see how nature shapes human endeavors in the American West, where distance and aridity have been pitted against our dreams and courage. The monument presents exemplary opportunities for geologists, paleontologists, archeologists, historians, and biologists.

The monument is a geologic treasure of clearly exposed stratigraphy and structures. The sedimentary rock layers are relatively undeformed and unobscured by vegetation, offering a clear view to understanding the processes of the earth's formation. A wide variety of formations, some in brilliant colors, have been exposed by millennia of erosion. The monument contains significant portions of a vast geologic stairway, named the Grand Staircase by pioneering geologist Clarance Dutton, which rises 5,500 feet to the rim of Bryce Canyon in an unbroken sequence of great cliffs and plateaus. The monument includes the rugged canyon country of the upper Paria Canyon system, major components of the White and Vermilion Cliffs and associated benches, and the Kaiparowits Plateau. That Plateau encompasses about 1,600 square miles of sedimentary rock and consists of successive south-to-north ascending plateaus or benches, deeply cut by steep-walled canyons. Naturally burning coal seams have scorched the tops of the Burning Hills brick-red. Another prominent geological feature of the plateau is the East Kaibab Monocline, known as the Cockscomb. The monument also includes the spectacular Circle Cliffs and part of the Waterpocket Fold, the inclusion of which completes the protection of this geologic feature begun with the establishment of Capitol Reef National Monument in 1938 (Proclamation No. 2246, 50 Stat. 1856). The monument holds many arches and natural bridges, including the 130-foot-high Escalante Natural Bridge, with a 100 foot span, and Grosvenor Arch, a rare "double arch." The upper Escalante Canyons, in the northeastern reaches of the monument, are distinctive: in addition to several major arches and natural bridges, vivid geological features are laid bare in narrow, serpentine canyons, where erosion has exposed sandstone and shale deposits in shades of red, maroon, chocolate, tan, gray, and white. Such diverse objects make the monument outstanding for purposes of geologic study.

The monument includes world class paleontological sites. The Circle Cliffs reveal remarkable specimens of petrified wood, such as large unbroken logs exceeding 30 feet in length. The thickness, continuity and broad temporal distribution of the Kaiparowits Plateau's stratigraphy provide significant opportunities to study the paleontology of the late Cretaceous Era. Extremely significant fossils, including marine and brackish water mollusks, turtles, crocodilians, lizards, dinosaurs, fishes, and mammals, have been recovered from the Dakota, Tropic Shale and Wahweap Formations, and the Tibbet Canyon, Smoky Hollow and John Henry members of the Straight Cliffs Formation. Within the monument, these formations have produced the only evidence in our hemisphere of terrestrial vertebrate fauna, including mammals, of the Cenomanian-Santonian ages. This sequence of rocks, including the overlaying Wahweap and Kaiparowits formations, contains one of the best and most continuous records of Late Cretaceous terrestrial life in the world.

Archeological inventories carried out to date show extensive use of places within the monument by ancient Native American culture. The area was a contact point for the Anasazi and Fremont cultures, and the evidence of this mingling provides a significant opportunity for archeological study. The cultural resources discovered so far in the monument are outstanding in their variety of cultural affiliation, type and distribution. Hundreds of recorded sites include rock art panels, occupation sites, campsites and granaries. Many more undocumented sites that exist within the monument are of significant scientific and historic value worthy of preservation for future study.

The monument is rich in human history. In addition to occupations by the Anasazi and Fremont cultures, the area has been used by modern tribal groups, including the Southern Paiute and Navajo. John Wesley Powell's expedition did initial mapping and scientific field work in the area in 1872. Early Mormon pioneers left many historic objects, including trails, inscriptions, ghost towns such as the Old Paria townsite, rock houses, and cowboy line camps, and built and traversed the renowned Hole-in-the-Rock Trail as part of their epic colonization efforts. Sixty miles of the Trail lie within the monument, as does Dance Hall Rock, used by intrepid Mormon pioneers and now a National Historic Site.

Spanning five life zones from low-lying desert to coniferous forest, with scarce and scattered water sources, the monument is an outstanding biological resource. Remoteness, limited travel corridors and low visitation have all helped to preserve intact the monument's important ecological values. The blending of warm and cold desert floras, along with the high number of endemic species, place this area in the heart of perhaps the richest floristic region in the Intermountain West. It contains an abundance of unique, isolated communities such as hanging gardens, tinajas, and rock crevice, canyon bottom, and dunal pocket communities, which have provided refugia for many ancient plant species for millennia. Geologic uplift with minimal deformation and subsequent downcutting by streams have exposed large expanses of a variety of geologic strata, each with unique physical and chemical characteristics. These strata are the parent material for a spectacular array of unusual and diverse soils that support many different vegetative communities and numerous types of endemic plants and their pollinators. This presents an extraordinary opportunity to study plant speciation and community dynamics independent of climatic variables. The monument contains an extraordinary number of areas of relict vegetation, many of which have existed since the Pleistocene, where natural processes continue unaltered by man. These include relict grasslands, of which No Mans Mesa is an outstanding example, and pinon-juniper communities containing trees up to 1,400 years old. As witnesses to the past, these relict areas establish a baseline against which to measure changes in community dynamics and biogeochemical cycles in areas impacted by human activity. Most of the ecological communities contained in the monument have low resistance to, and slow recovery from, disturbance. Fragile cryptobiotic crusts, themselves of significant biological interest, play a critical role throughout the monument, stabilizing the highly erodible desert soils and providing nutrients to plants. An abundance of pack rat middens provides insight into the vegetation and climate of the past 25,000 years and furnishes context for studies of evolution and climate change. The wildlife of the monument is characterized by a diversity of species. The monument varies greatly in elevation and topography and is in a climatic zone where northern and southern habitat species intermingle. Mountain lion, bear, and desert bighorn sheep roam the monument. Over 200 species of birds, including bald eagles and peregrine falcons, are found within the area. Wildlife, including neotropical birds, concentrate around the Paria and Escalante Rivers and other riparian corridors within the monument.

Section 2 of the Act of June 8, 1906 (34 Stat. 225, 16 U.S.C. 431) authorizes the President, in his discretion, to declare by public proclamation historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest that are situated upon the lands owned or controlled by the Government of the United States to be national monuments, and to reserve as a part thereof parcels of land, the limits of which in all cases shall be confined to the smallest area compatible with the proper care and management of the objects to be protected.

Now, Therefore, I, William J. Clinton, President of the United States of America, by the authority vested in me by section 2 of the Act of June 8, 1906 (34 Stat. 225, 16 U.S.C. 431), do proclaim that there are hereby set apart and reserved as the Grand Staircase-Escalante National Monument, for the purpose of protecting the objects identified above, all lands and interests in lands owned or controlled by the United States within the boundaries of the area described on the document entitled "Grand Staircase-Escalante National Monument" attached to and forming a part of this proclamation. The Federal land and interests in land reserved consist of approximately 1.7 million acres, which is the smallest area compatible with the proper care and management of the objects to be protected.

All Federal lands and interests in lands within the boundaries of this monument are hereby appropriated and withdrawn from entry, location, selection, sale, leasing, or other disposition under the public land laws, other than by exchange that furthers the protective purposes of the monument. Lands and interests in lands not owned by the United States shall be reserved as a part of the monument upon acquisition of title thereto by the United States.

The establishment of this monument is subject to valid existing rights.

Nothing in this proclamation shall be deemed to diminish the responsibility and authority of the State of Utah for management of fish and wildlife, including regulation of hunting and fishing, on Federal lands within the monument.

Nothing in this proclamation shall be deemed to affect existing permits or leases for, or levels of, livestock grazing on Federal lands within the monument; existing grazing uses shall continue to be governed by applicable laws and regulations other than this proclamation.

Nothing in this proclamation shall be deemed to revoke any existing withdrawal, reservation, or appropriation; however, the national monument shall be the dominant reservation.

The Secretary of the Interior shall manage the monument through the Bureau of Land Management, pursuant to applicable legal authorities, to implement the purposes of this proclamation. The Secretary of the Interior shall prepare, within 3 years of this date, a management plan for this monument, and shall promulgate such regulations for its management as he deems appropriate. This proclamation does not reserve water as a matter of Federal law. I direct the Secretary to address in the management plan the extent to which water is necessary for the proper care and management of the objects of this monument and the extent to which further action may be necessary pursuant to Federal or State law to assure the availability of water.

Warning is hereby given to all unauthorized persons not to appropriate, injure, destroy, or remove any feature of this monument and not to locate or settle upon any of the lands thereof.

In Witness Whereof, I have hereunto set my hand this eighteenth day of September, in the year of our Lord nineteen hundred and ninety-six, and of the Independence of the United States of America the two hundred and twenty-first.

William J Clinton

WILLIAM J. CLINTON

Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it is the only thing that ever has.

Margaret Mead